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CARDIAC SYNDROMES COMPLICATING DIABETES AND THEIR TREATMENT

BY

K. SHIRLEY SMITH

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While it is true that common diseases must often co-exist in the same patient, the frequent association of heart disease with diabetes is the expression of a causal relationship. In the present paper the evidence for this statement will be examined. Thereafter an analysis will be made of 49 patients with heart disease and diabetes, with a discussion of the nature of the anginal and other cardiac syndromes developing, and typical clinical examples will be mentioned. Lastly, schemes of treatment for the various combinations of these maladies will be outlined.

That diabetes conduces to early, serious, and often fatal cardiovascular disease has been suspected for more than fifty years (Vergely, 1881 ; Frerichs, 1883), but pathological and clinical data have become available chiefly during the past decade. Blotner (1930) in necropsies of 77 diabetics found conspicuous disease of the coronary arteries in 45 per cent ; cardiac infarction was the cause of death in 10 per cent, the ages ranging from 13 to 85 years; these figures contrasted with a 21 per cent incidence of coronary sclerosis in 450 non-diabetics between the ages of 40 and 80 years. Warren (1930) found coronary thrombosis and cardiac infarction in 12 per cent of necropsies among diabetics, and commented on the frequency with which diabetics with advanced coronary sclerosis escaped angina. Root and Graybiel (1931), in a study of 210 cases of diabetes with angina, stated their experience that at necropsy every patient with a five-year history of diabetes had some degree of coronary sclerosis: they drew their 210 anginal patients from a series of 7000 diabetics, an incidence far in excess of that in an ordinary hospital population. Moreover, they found that diabetes exerted a levelling influence upon the sex incidence of angina (122 males and 88 females). For every patient in whom angina preceded diabetes, there were 21 in whom diabetes had preceded angina.

A comparison of the atherosclerotic lesions found at necropsy among 349 diabetics and those found in 3400 non-diabetics has been made by Root, Bland, Gordon, and White (1939). Coronary occlusion was much more frequent among the diabetics (23 compared with 6 per cent, between the ages of 40 and 60). In the same age group, 17 per cent of diabetics had coronary narrowing without occlusion, as against 12 per cent in non-diabetics. Clinical studies leading to similar conclusions have been made by Friedman (1935), who demonstrated aortic sclerosis by clinical methods in 75 per cent of 120 diabetics over 39 years of age. The high incidence of hypertension in diabetes has been shown by Root and Sharkey (1936); high blood pressure was present in 54 per cent of their series of 175 diabetics. They noted that coronary changes were absent only when diabetes was of less than three years' standing, and that advanced coronary sclerosis was twice as frequent in diabetics as in non-diabetics. Bell and Clawson (1928) found hypertension in 42 per cent of diabetics over the age of 50. Parallel to these clinical findings were the observations of Lehnherr (1933) who compared the cholesterol and calcium contents of aortas from diabetics and non-diabetics, and found exaggerated lipoid changes and greater calcium and phosphorus deposits in the diabetic aortas.

These pathological and clinical facts relating to the heart and aorta are consistent with the well-established relationship between diabetes and arteriosclerosis. That diabetes conduces to early and progressive general arteriosclerosis is no longer open to question in the light of the studies of Heitz (1923), Joslin (1927), Shepardson (1930), Priscilla White (1932), Leary (1935), and Root and Sharkey (1936). Shepardson gave radiological evidence of a 36 per cent incidence of calcification in the arteries of the legs in diabetics up to the age of 40, the average being 23 years. White gave similar results among diabetic children up to 15 years of age (19 out of 106 cases). Although these results strongly suggested that the diabetic condition conduced to arteriosclerosis, it could still be argued that arteriosclerosis and diabetes took origin from some common antecedent constitutional abnormality.

The work of Root and Sharkey (1936) gave additional evidence of a causal relation between diabetes and arteriosclerosis. They compared the necropsy findings of 175 diabetics of all ages with

those of 170 non-diabetics all over 40 years of age. A striking excess of arteriosclerotic lesions was found in the former group, but there was still the possibility that the arterial lesions began before the diabetes. To elucidate this point they investigated the arterial condition at necropsy of 23 diabetics of less than one year's duration. This group showed rather less arterial change than a control group of 170 non-diabetics. A similar disparity was recorded in the condition of the coronary arteries in the two groups. Moreover, as Root and Graybiel (1931) have pointed out, diabetes most frequently develops at 51 years, while diabetic angina occurs most commonly in the decade in which ten-year cases of diabetes are most numerous. These considerations, coupled with the levelling influence of diabetes upon the sex distribution of angina, point unmistakably to diabetes with its associated metabolic change as contributing to bring about arteriosclerosis in general and decrease of the coronary artery in particular. As Levine (1929) has demonstrated, diabetes must be accorded a place only subsidiary to that of high blood pressure among the morbid states conducing to coronary thrombosis.

Clinical Observations in Present Series

The present observations are based upon 49 consecutive patients in whom diabetes co-existed with cardiovascular disease. The diabetes was of every grade from symptomless mild diabetes, proved by sugar tolerance curves, to gravely toxic or comatose stages. Cardiovascular disease similarly ranged from symptomless hypertension to acute coronary occlusion with high grades of shock. Diabetes accompanied only by peripheral arterial disease was not included. The sex distribution was fairly even: 26 females to 23 males. The average age of the women was 61, that of the men 62 years. The cardiovascular disease was always founded on hypertensive or degenerative lesions or both ; no example of rheumatic, syphilitic, or thyrotoxic heart disease in association with diabetes was encountered. But although the ætiology of the cardiac complications was strictly limited, a wide range of disorders of function was observed, such as left ventricular failure with cardiac asthma, congestive failure with œdema, and various forms of angina.

A very frequent accompaniment of diabetes was hypertension; this was present in 41 cases and in 3 others there was evidence that it had previously existed, making 44 out of the total of 49 cases. In general the grade of hypertension was far from trivial; in 31 instances the systolic blood pressure was 180 or more, compared with 13 in which it was under 180 mm. As striking as the prevalence of hypertension was the reduction in blood pressure during treatment. This fact and the observation that the reduction of pressure during stabilization of the diabetes was not uncommon, even in patients previously confined to bed, suggested that hypertension in these cases was in part attributable to the immediate metabolic fault.

Relation of Cardiovascular Disease to Diabetes

The patients comprising the present series fell naturally into certain categories. Some were aware of the existence of heart disease and diabetes at the time they first came under observation; of these a few had been or were still on insulin treatment, while others had never received this. Frequently a patient known to be diabetic presented himself with the initial symptoms of cardiovascular disease; rarely the converse relationship held. A well-defined group were those who had regarded themselves as well but now manifested symptoms of diabetes or of heart disease and were subsequently shown to possess a cardiopathy or diabetes respectively.

Group I. Patients known to have diabetes and cardiovascular disease (18 *of present series*).

These are often diabetics of long standing and the disease may be of a grade to require insulin treatment. It is well known that too great a dosage of insulin may provoke an anginal attack and this may culminate in coronary thrombosis. Equally, congestive heart failure or left ventricular failure may develop by the same mechanism. On the other hand, the dosage may be too small (actually, or relatively as a result of intercurrent infection). Coronary thrombosis is specially apt to occur in the diabetic, but there is evidence that inappropriate dosage of insulin may conduce to this accident. Some patients may never have had insulin treatment, although obviously in need of it when they come under observation. This commonly arises through the diabetes being at first slight and easily controlled by diet alone; gradually the fault becomes more severe and perhaps the patient has ignored warning sysmptoms of this process; finally, a cardiac attack discloses the untrolled or untreated diabetes. Evidence that the onset of effort angina, coronary thrombosis, cardiac asthma, or chronic congestive failure is attributable to the diabetic fault will be adduced below.

Group II. Patients known to have diabetes, developing cardiovascular symptoms (12 *cases*).

Patients of this group may seek advice on account of slight disorders, such as undue fatigue, shortness of breath, bouts of dizziness, or attacks of faintness. In a few cases one of the major seizures mentioned in the preceding section may be the first indication that cardiovascular disease has been developing.

Group III. Patients known to have cardiovascular disease, developing symptoms due to diabetes (5 *cases*).

The fact that relatively so few patients belong to this category is consistent with the established fact that diabetes is important in the ætiology of heart disease. In view of this relationship it would be surprising if many patients experienced symptoms of cardiac lesions before those of diabetes.

Group IV. Patients previously believed well, in whom the occurrence of a cardiac or a diabetic syndrome brings to light the existence of diabetes or heart disease respectively (14 *cases*).

It is remarkable that in so many patients diabetes and its cardiac complication may reach a fairly advanced stage without either of them causing obtrusive symptoms, but it is in keeping with the observation of Warren (1930) and other workers that necropsy in the diabetic may disclose advanced coronary sclerosis although there had been no symptoms of angina. In general it is uncommon for a grave diabetic development to occur in heart disease, or for a serious cardiac attack to complicate diabetes unless the patient has had early symptoms of one or other or both maladies previously.

While it might be more logical to consider the various cardiac disorders that may be observed in these groups of patients, it will save repetition if cardiac syndromes are reviewed in turn, the various circumstances in which each may occur being shown by reference to illustrative cases. The following will be dealt with : effort angina, coronary thrombosis, cardiac asthma, and congestive heart failure.

Various Cardiac Syndromes

Effort angina and spasmodic angina. This may be the natural and not unexpected expression of coronary sclerosis, and may develop in the manner so often seen in patients who have no diabetes. Nevertheless, while it is obvious that the heart of the diabetic must be provided with more than sufficient sugar for its needs, the failure to utilize this source of energy may lead to anginal attacks that are abolished by the use of insulin. Hetenyi (1927) has reported examples. This process has been observed in the present study in a man aged 53 in whom bouts of pain and oppression in the chest became much less frequent and severe as the fasting blood sugar fell from 315 to 219 mg. per 100 c.c. on treatment by insulin, 10 units twice daily, and a diet of 1800 calories. (Case 1.)*

The rapid fluctuations of blood sugar that may take place from various causes in the diabetic patient who is on insulin treatment entail sudden alterations in the nutrition of the heart. As effort angina may correspond to these phases of imbalance, this indicates that anginal pain in the diabetic (and perhaps also in the non-diabetic) is not only related to ischæmia but also to metabolic disorders in the heart muscle, a phenomenon discussed in a previous publication (Shirley Smith, 1933). Angina produced by an excessive lowering of blood sugar in a patient taking too large a dose of insulin has been called " insulin angina ". Fortunately no syndrome of this kind was evoked during treatment in any cases of the present series.

Coronary thrombosis and cardiac infarction. Coronary thrombosis occurs with greater frequency among diabetics than among non-diabetics of the same age group. Its incidence is greater among diabetics who need, but are not taking, insulin. Thus an elderly female with long-standing glycosuria and hypertension developed increasing fatigue as a result of undue activity. After transient anginal attacks on three successive nights she developed coronary thrombosis, with congestive heart failure. By the use of digitalis and insulin therapy and the restriction of her fluid intake to 2 pints in 24 hours, she recovered and remained in good health for over three years when heart failure recurred. (Case 2.)

Patients who are on insulin treatment for diabetes are by no means protected from coronary thrombosis, even though the correct dosage seems to have been found. In a woman who was admitted with a ten-year history of diabetes, lethargic, dehydrated, and stuporous, the immediate danger was averted, but in spite of apparently successful adjustment of insulin dosage, signs of collapse recurred. Death ensued 19 hours after the onset, and necropsy confirmed the diagnosis of coronary thrombosis. (Case 3.)

When patients are on treatment by diet and insulin the sudden reduction or withdrawal of insulin may mark the onset of coronary thrombosis. In one instance the development of the attack followed

* Full case histories were submitted, but unfortunately had to be left out owing to reduction in the paper allowance.—Editor.

the omission of a dose of insulin the previous evening. A blood sugar level of 600 mg. per 100 c.c. showed that there had been progressive loss of control of the diabetes through inadequate dosage of insulin. (Case 4.)

It is not unusual for coronary thrombosis to occur as the initial expression of heart disease in a patient known to be diabetic. In some instances it develops with increasing hyperglycæmia and acetonæmia: in others diabetic coma may be the immediate sequel of acute coronary occlusion; e.g. a woman diabetic, aged 55, had an attack of coronary thrombosis, and about 60 hours after the onset she had become unconscious and extremely restless, and the blood sugar was found to be 650 mg. per 100 c.c.; she died very soon after the institution of treatment. (Case 5.)

While it is common for heart disease to develop in the diabetic the reversal of the order is comparatively rare. Only 5 examples were observed in the present series of 49 patients. In one, a female of 63, there was a history of effort angina for three years; during an acute pulmonary infection glycosuria was observed for the first time. (Case 6.) In another, a physician aged 57, there was undue fatigue six months after recovery from coronary thrombosis; he was found to have a low renal threshold, but the fact that his condition conspicuously improved with reduction of carbohydrate intake suggested that a fault of metabolism also existed. (Case 7.)

Coronary thrombosis often occurs without any warning symptoms of heart disease, and routine examination at the time may bring to light the existence of diabetes. This sequence of events was recorded in a female, aged 54, who complained essentially of pain in the left arm. Routine examination disclosed diabetes; she was admitted to hospital with evidence of a recent TIII type of cardiac infarction. She recovered and was discharged on a weighed diet of 2000 calories and 10 units of insulin daily, which allowed intermittent glycosuria. Death occurred suddenly a few months later. (Case 8.)

The intensity of arterial disease and its rapid progress in the diabetic offer an obvious explanation of the frequency with which anginal syndromes are observed. When cardiac breakdown occurs in forms that represent myocardial as distinct from coronary failure, the relationship is not so clear. In some patients in the present series, cardiac asthma was a circulatory expression of uncontrolled diabetes, suggesting that left ventricular failure might result from an untreated or a badly corrected fault in carbohydrate metabolism. Syndromes of this order suggest that diabetes exerts a deleterious effect on the myocardium, not only by virtue of coronary sclerosis but also through direct impairment of the parenchyma of the heart. That general heart failure with congestion and œdema may be the consequence of untreated diabetes will be suggested later, but the fact may be referred to at this point as demonstrating further the myocardial (as distinct from coronary) damage that may develop.

Cardiac Asthma. Cardiac asthma, following the aggravation of a latent diabetes associated with long-standing hypertension, was observed in the following instance. A woman, aged 41, had severe hypertension, and was seen at intervals for five years, glycosuria being found on one occasion. Twenty-four hours after a motor accident in which she was shocked but not injured, she experienced thirst and on the following night had cardiac asthma. Investigation disclosed severe diabetes. At the time of discharge on a fixed diet of 2000 calories, with insulin, 7 units twice daily, she was free from cardiac or diabetic symptoms, but showed intermittent glycosuria. (Case 9.)

It is not surprising that left ventricular failure and ultimately general congestive failure sometimes succeed effort angina in diabetes, as this sequence of events is commonly seen in coronary sclerosis without diabetes. In Case 10 cardiac asthma was the presenting symptom at the time of admission. A male, aged 58, had been a diabetic taking insulin for 7 years. For 18 months he had experienced effort angina. Cardiac asthma had supervened, and later signs of congestive heart failure. After admission to hospital and adjustment of insulin dosage, the paroxysms of dyspnœa came to an end and the signs of failure vanished. These events might be explicable on the basis of rest alone, were it not for the fact that rest had been employed without success prior to admission and that in hospital no relief from the cardiac asthma was obtained until adjustment of insulin dosage had been effected.

In another instance a woman, aged 60, had suffered for several years with diabetes and hypertension. Paroxysmal dyspnœa, chiefly nocturnal, developed, and relief from these distressing attacks synchronized with adjustment of the insulin dosage and diet. (Case 11.)

Congestive heart failure. While coronary arterial disease finds its most characteristic expression in anginal attacks of various kinds, it may culminate in congestive heart failure without painful episodes at any time. The development of failure in the diabetic would therefore not be surprising, and it might be regarded as entirely independent of the diabetic state except in so far as the latter conduced to coronary sclerosis. The disturbances of cardiac nutrition in diabetes may play a part in the development of failure, and stabilization may bring improvement in the circulatory condition. A man of 69 was admitted with congestive heart failure; he had been diabetic for 33 years. Severe dyspnœa persisted in spite of control of the hyperglycæmia and acetonæmia. Blood sugar examination showed that too great a reduction had been secured (56 mg. per 100 c.c.). A reduction in insulin

dosage allowed the blood sugar to rise to 222 mg. and signs of failure progressively disappeared. Failure re-appeared a month or two later, and on several occasions during this phase intravenous injections of glucose relieved severe paroxysms of dyspnœa. (Case 12.)

In another case of congestive failure following cardiac infarction, a choice had to be made between a free fluid intake to combat impending coma, and a restricted intake indicated by the orthopnœa and congestive failure. Further reference to the therapeutic dilemma is made hereafter in the consideration of treatment.

Treatment of the Cardiac Diabetic

As has been shown, the syndromes resulting from the cardiac complications of diabetes are of great variety. They are in fact often the same as those met with in patients who are not diabetic; in these treatment will be primarily directed to the circulatory condition, but treatment of the metabolic fault may never be ignored with impunity. In others the clinical features represent a blend between the effects of the cardiovascular disease and nutritional and toxic consequences of the diabetes; here treatment will call for an appraisal of the relative importance of the two elements: since the requirements of the one may be at variance with those of the other, great difficulty may be experienced in deciding upon the most suitable scheme of treatment. In yet others circulatory collapse of the second type described by Frerichs (1883) may complicate diabetic coma without any indication of congestive failure or coronary thrombosis. Experience shows that many of such patients may in the initial grave cardiac attack succumb within a few hours or days, the falling blood pressure and progressive collapse resisting all therapeutic efforts. The treatment of syndromes of this type has been studied by many workers (Labbe & Boulin, 1928 & 1933; Lawrence, 1933; and Clerc, 1934). Equally, the patient may be treated with the necessary precautions to be mentioned below, may make great improvement in the heart and diabetes, and yet may die suddenly without obvious immediate cause when he appeared to be well on the way to convalescence. These difficulties have been described by several observers (Haynal, 1925; and Soskin, Katz, Strouse, & Rubinfeld, 1933).

When a cardiac disease such as effort angina supervenes in a diabetic whose condition has been long recognized and kept under control, treatment will naturally first be directed to the necessary adjustments in the mode of life and to appropriate medicinal measures for the relief and prevention of pain. Nevertheless the development of angina will prompt an immediate survey of the diabetic state. While it has long been regarded as unwise to treat vigorously by diet diabetes in later life, it is specially dangerous to treat diabetes in the cardiac patient as a pure problem of diabetic stabilization. Sudden alterations of blood sugar by diet or insulin are not well tolerated. Treatment on the metabolic side will therefore be directed essentially to the avoidance of acetonæmia; if glycosuria persists in spite of qualitative or maintenance dieting, insulin may be used, but always in less quantity than would be employed if the same patient were free from signs of a cardiac fault. In general, it is safer for these patients to live with a moderate hyperglycæmia and to have glycosuria from time to time, than to be strictly controlled and rendered constantly free from sugar. This is because the myocardium may depend for its nutrition upon hyperglycæmia off-setting the deficient coronary flow.

Diet will be an important element in the treatment of all cardiac diabetics. Sometimes general and qualitative restriction (of bread, sugar, potatoes) is all that is required, but in many cases a full quantitative system will be necessary, with the number of calories laid down. The construction of such a diet with sufficient variety will not be difficult on the Lawrence line-ration scheme. Cardiac diabetics and in fact all diabetics should restrict foods of high cholesterol value such as eggs, cream, butter, cheese, and brains.

More complex situations arise when the diabetic develops such a condition as congestive heart failure or left ventricular failure with cardiac asthma. Here again the cardiovascular syndrome may be no different from one that might be seen apart from diabetes, and may seem to bear little relation to the metabolic fault, but as we have endeavoured to show in the cases mentioned, the therapeutic test may indicate that a close relationship exists between the circulatory breakdown and some maladjustment or failure of management of the diabetes. If no insulin was previously needed it may become necessary, owing to the increased basal metabolism in heart failure, to fever which sometimes accompanies failure, or to the disorganization of digestion and assimilation caused by congestion. On the other hand, if insulin were being taken the dose might need to be increased or decreased. Aggravation may be due equally to excess or deficiency of insulin.

Estimations of blood sugar (both fasting and three-quarters of an hour after a meal) coupled with frequent examination of the urine for sugar and acetone bodies will be essential. The ferric chloride (Gerhardt) test will in the first instance give more assistance than the Rothera test by providing a demarcation between grosser and milder grades of ketosis. If the ferric chloride test and clinical features show that there is little or no ketosis, the immediate danger of the patient is little more

than might be attributed to the heart failure alone. A careful review of the metabolic condition and analyses of blood and urine will be essential, and it may or may not be found necessary to give insulin or to adjust a dosage previously in use. In any case rather less insulin will be given than would be the case if no cardiac lesion were manifest. If the ferric chloride test is positive, and particularly if other indications of severe ketosis are present (rising pulse, abdominal pain, furred tongue, and headache), treatment of the diabetes will become of preponderating importance and urgency. The intake of fluid by mouth will be increased to six or eight ounces each hour, and insulin and glucose in the proportion of one unit of insulin to rather more than one gram of glucose. As the occasion will be one of great urgency, no accurate weighing of glucose will be practicable; roughly, a full (not heaped) tablespoonful of glucose contains fifteen to sixteen grams. Therefore a dose of twenty-five or thirty units of insulin would be suitably combined with two tablespoonfuls of glucose; these doses might be repeated once or more at intervals of two to four hours according to the needs of the individual case. Insulin will usually be given intramuscularly, but may be given intravenously if the condition is grave; the glucose will be given orally whenever possible, but if not, by rectal or intravenous infusion. It is obvious that each case will require assessment on its merits and that no hard and fast rules can be laid down. Nevertheless, the following points are of great importance in all cases in which a cardiovascular lesion of more than trivial grade is accompanied by diabetes with ketosis or impending coma.

1. The situation is grave and therapy urgent.
2. No time should be lost awaiting the results of laboratory investigations.
3. Immediate attention should be paid to the essentials of treatment for the diabetic complication, by the provision of warmth and rest, the increase of fluids by mouth, and the provision of stimulants, such as hot coffee or tea.
4. The use of insulin, coupled with more than balancing amounts of glucose added to the drinks or the infusions, is important.
5. From the cardiac standpoint warmth and rest are equally essential, the degree of recumbency depending upon the patient's wish.
6. Repeated examinations of urine will be necessary; it should not become constantly sugar-free but the aim is to abolish ketosis; blood sugar (fasting) should be estimated every few days and levels lower than 130 or 140 are to be avoided.

The association of diabetic coma with coronary thrombosis is one of the most desperate medical emergencies. The combination may take the following forms: coronary thrombosis may occur in a previously stabilized diabetic and induce coma; a diabetic may become unstabilized through some lapse in treatment or diet, or through some intercurrent infection, and then develop coronary thrombosis. In other cases the patient passes insidiously into diabetic coma with associated symptoms suggesting coronary disorder (pain or oppression in the chest); in these it may only be the course of events that will show whether or not a coronary occlusion has occurred. If it has, there will be either a fatal issue or a very protracted and dangerous illness; if it has not, the treatment directed to the coma will usually be followed by very rapid recovery. Neither the electrocardiogram nor its evolution in serial records is of conclusive help in this diagnosis, because in coronary thrombosis no change may be seen in the first few days (which are important ones from the standpoint of treatment), while in severe diabetes without coronary complications cardiographic changes very similar to those of coronary occlusion are sometimes found (Shirley Smith & Hickling, 1933; and Bellet & Dyer, 1937); however, the evolution in serial records is rather different in this case.

The problem of fluid administration is often difficult and sometimes insoluble in the treatment of heart failure associated with diabetes, of coronary thrombosis complicated by diabetes, and of diabetic coma or impending coma when severe heart disease exists. It is accepted that in congestive heart failure the fluid intake should be limited to 25 or 30 oz., and the same rule applies to treatment in the early days of acute coronary occlusion which has produced more than trivial constitutional upset. At the same time in each of the three examples cited, the appropriate treatment of the diabetes demands administration of perhaps four or five pints of fluid in the twenty-four hours, or if dehydration has developed, double these quantities, even if part has to be given by rectal or intravenous routes. The impossibility of reconciling these diametrically opposed requirements in the same patient is the reason why treatment is so often unavailing and why combined maladies of these kinds are so lethal.

In spite of these obvious difficulties there are certain general principles underlying fluid administration which should be observed in constructing a scheme of treatment.

In congestive heart failure accompanied by severe diabetes it is better to risk the development or increase of œdema than to allow progressive hyperglycæmia and ketosis. It will therefore be better to give sufficient fluid (in addition to other medication such as insulin) to minimize the risk of coma. Consequent œdema may be later dispersed by the mercurial diuretics, whereas increasing ketosis will

certainly aggravate failure even though no œdema exists. If diabetic coma is present the intravenous route must be used for the administration of fluid and glucose. The signs of dehydration denote a total fluid lack of perhaps 10 to 12 pints, and large quantities of fluid must therefore be given in a relatively short time (Lawrence, 1930). In Case 4 of the present series there was no doubt that the intravenous infusion of 10 per cent glucose saline helped in the relief of dangerous collapse due to the combined effects of severe diabetic ketosis (blood sugar 600 mg. per 100 c.c.) and coronary thrombosis.

Summary

The evidence proving that diabetes conduces to early and severe arteriosclerosis and, specially, to coronary arterial disease and coronary thrombosis has been reviewed.

The clinical features of 49 consecutive cases of diabetes associated with heart disease have been analysed. The sexes were fairly evenly represented; the average age of the men was 62 years, and that of the women 61 years.

Hypertension was present in 44 of the 49 patients (almost 90 per cent); in 31 instances the blood pressure was 180 mm. or more. As is usual in hypertension uncomplicated by diabetes, the blood pressure frequently dropped swiftly and considerably on confining the patients to bed. Reasons have been given for believing that hypertension in the diabetic was in some degree directly attributable to the metabolic fault.

A study was made of the manner in which angina of effort, spasmodic angina, coronary thrombosis, left ventricular failure, and congestive heart failure supervened in diabetics. Some case histories illustrating these events and showing the relationship between the diabetic state and the cardiac development have been summarized.

As a rule, patients with diabetes and one or other form of angina or heart failure were found to derive benefit from any necessary readjustments of regime or insulin dosage. Controlled observations were not, for obvious reasons, generally possible, but in a few patients, in whom this adjustment *only* was made, deterioration in the heart condition was replaced by improvement.

It has been concluded that while the lives of patients with disease of a coronary artery are at serious risk those of the " cardiac diabetics " are even more precarious. Coronary thrombosis in the diabetic is extremely hazardous.

Methods of treating cardiac complications in diabetes have been reviewed. The requirements of diet, fluid, insulin, glucose, and remedies directed to the heart have been considered. The well-known principle, that in patients with heart disease sudden reductions of blood sugar by diet or insulin are not well tolerated, has been endorsed in the present study. In general the use of insulin will be in such dosage as may be necessary to abolish acetonæmia and reduce severe hyperglycæmia. To use insulin to procure stabilization or exact control of the diabetes in patients with additional heart disease is to court disaster.

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CONGENITAL HEART BLOCK WITH DEXTROCARDIA

BY

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From the Highlands and Islands Medical Service

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Stein and Uhr (1941), describing congenital heart block in a girl of 3, bring the total of reported cases to 55. Apparently the number that are recognized and reported is still not great, since Campbell and Suzman (1934) analysed 53 which they accepted as fulfilling the criteria of diagnosis. Associated anatomical defects of the heart always seem to be present, and, as might be expected, septal defects are common, if not invariable. It has not been suggested that any case of incomplete heart block is congenital: partial and transient heart block is, of course, common enough in the acute infections, but if it should become complete, the patient usually dies. Fishberg (1940) saw one patient who survived with complete block that was apparently due to diphtheria, and quotes Stechner's study of 19 others, all of whom died. White (1937) thinks acquired cases apart from coronary disease are rare. The age of the patient is therefore a fair indication of the ætiology of complete heart block that persists, i.e. coronary disease in middle age and congenital defect in childhood and early adult life, and this rule will be subject to few exceptions. Writers have rather tended to insist that the cause of complete heart block in children and young adults should be assumed to be infection unless there is proof of its congenital origin, and Yater (1939) gives several criteria for the diagnosis. It seems likely, however, that most, if not all, cases of complete heart block in children and young adults are congenital, and the mere history of a severe infectious disease is no proof of ætiology. There must be few children in whom a history of one or other of the infectious diseases cannot be discovered, and one would need to have seen the appearance of block during the course of the infection to assume that this had been responsible. Such an observation, of course, has often been made in diphtheria, but survival after its appearance must be rare. The existence of *any* other evidence of congenital heart disease would be strong presumptive evidence that the heart block was also congenital. For example, Bower (1939) reports two cases as discovered after severe measles, but both had systolic murmurs that were probably due to septal defect.

A case of congenital heart block, with dextrocardia as part of a complete transposition of viscera, is here reported; she had the further peculiarity that she came under my notice with an acute primary tuberculous infection, and later developed extensive pulmonary tuberculosis, which, however, shows a strong tendency to heal. The association of complete heart block with dextrocardia must be very rare; I have only found reference to one other case (Yater, 1929). My patient had also the signs of septal defect.

Brown (1939), making a rather narrower selection of cases of complete heart block than that of Campbell and Suzman (1934), accepts 44 as being congenital, of which 27 had clear signs of a septal defect, confirmed in 5 by autopsy. He considers the rarity of congenital complete heart block fully explained by the fact that the A-V bundle develops in the fœtus before the formation of the septum, so that a defective septum is unlikely to interfere with conduction. The heart rate is not so slow as it is in adult acquired block, and may increase to 80 under certain conditions. The ordinary ventricular rate at rest is usually about 50 ; it is more easily increased by stimuli than in acquired heart block, and this explains why, unless a special search is being made for such cases, the condition may easily be overlooked. The subjects of congenital heart block may pass through a medical examination without the block being discovered.

Case Notes. H. G., aged 20, was admitted to the Royal Northern Infirmary on July 11, 1939. Three weeks before, there had been an eruption on the legs described as "a few small hard red tender spots," and at the same time she had pain in the legs on movement ; a week after this she had a succession of rigors and a pain in her chest with some shortness of breath. It had been known for some years that she had dextrocardia, and exertion had always made her breathless and cyanosed. There was no history of any relative having been affected in the same way. The parents were not related and had neither dextrocardia nor heart block. Information about other sibs was merely second-hand from the girl's mother, i.e. she had never heard of any congenital heart peculiarity.

When admitted she had slight fever (temperature 99·5 F.), but was in no discomfort. She was cyanosed, but respiration at rest was quite peaceful. There was obvious clubbing of fingers and toes. Complete transposition of viscera was present (Fig. 1). There was a dorsal scoliosis, the heart's apex

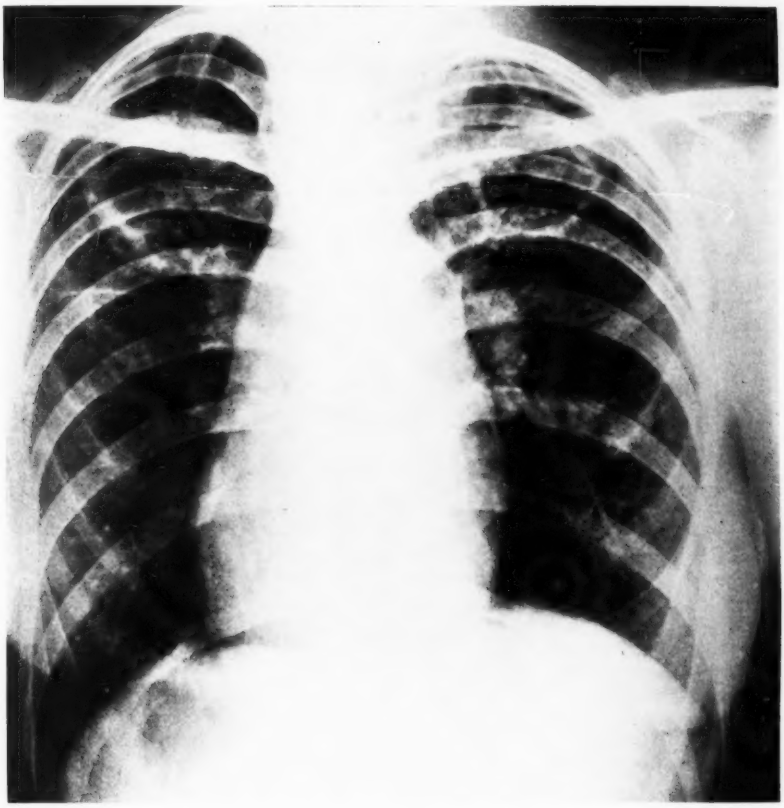

FIG. 1.—The chest in 1942, showing the development of tuberculous cavitation; there is also dextrocardia and enlargement of the " right " or pulmonary side of the heart, both of which had been present in the picture taken in 1939.

was to the right, and a loud rough systolic murmur was audible all over the præcordium with maximum intensity over the second right costal cartilage; there were no diastolic murmurs. The rhythm was regular, the rate 80, and the blood pressure 110/60 in the arms. The spleen and liver could not be felt, but there was dulness to percussion over the presumed site of the liver on the left side, and a small area of dulness over Gairdner's line (on the right side). No signs remained of the eruption on the legs and there were no petechial spots or hæmorrhages in the retina. A catheter specimen of urine showed a few red cells. The sedimentation rate (Westergren) was 80 and remained near this figure on repeated examination during her stay of four weeks in hospital; blood cultures were sterile. The cardiogram (Fig. 2) showed complete dissociation of auricle and ventricle, inversion of P I, and a deep Q I characteristic of the " mirror " picture of visceral transposition. T I, however, was positive. There was right axis deviation, which was consistent with hypertrophy of the pulmonary side of the heart due to septal defect.

The ventricular complex nowhere suggested an origin below the bifurcation of the bundle : this is to be expected, and is a usual feature of congenital heart block (Lampard, 1928). The auricular rate was 90–100 and the ventricular, 45–50.

The temperature fell to normal after 24 hours and the heart rate decreased until it reached its habitual frequency of 48 to 52. Exercise and subcutaneous adrenalin had no influence on the heart rate. The patient went home, and was kept in bed for two months: I saw her again three months after she left hospital, when she was getting about, in no distress.

FIG. 2.—Standard leads showing dissociation of auricle and ventricle, inversion of P_1, and right axis deviation.

I did not see her again until May, 1941, when hæmoptysis occurred: she had been working regularly as an accountant's clerk for more than 18 months, and was in good health until she was moved to a northern town in mid-winter, where the heating arrangements were poor in her lodgings: she developed a cold and cough, which continued for some weeks, when the sputum became frothy and bright red. No evidence of heart failure was found, and there were no definite signs to be made out in the lungs. She was reluctant to go to hospital but reported after some weeks, when an X-ray showed scattered infiltration in both lungs, and the sputum contained tubercle bacilli. The sedimentation rate was now 60. She remained in hospital for two months during which time her sedimentation rate fell to 21, and she then returned home, at her own desire, practically symptomless. Reviewed in July, 1942, her health was as good, she thought, as it had been before her first hæmoptysis; an X-ray showed cavitation in both upper lobes, but with a hardening of all the pulmonary shadows; there was no sputum, and the sedimentation rate was 15.

Brown quotes Abbot (1927) for the maximum age attained in congenital heart block as 20 years. My patient is already 23 and, apart from her tuberculosis, is in good health. Except to anatomists and embryologists, the interest of the condition lies mainly in the effect on the subject's functional capacity. Most writers on the subject agree that the expectation of life is governed rather by the associated heart defects than by the block. While the relative inelasticity of the heart rate must obviously limit the subject's power of sustained muscular effort, the impossibility of damaging tachycardia may prevent some wear and tear.

SUMMARY

A patient with congenital heart block, dextrocardia, and probable septal defect is reported. She also developed extensive pulmonary tuberculosis, but showed a good tendency to recovery, and attained the age of 23 with good functional capacity equal to office work. Her ventricular rate was about 50, but rose to 80 during fever: it was not influenced by exercise or adrenalin.

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CONGENITAL HEART BLOCK WITH ATRIAL AND VENTRICULAR SEPTAL DEFECT

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The combination of atrial septal defect with congenital complete heart block is of sufficient rarity to justify publication of the following case.

Case report.—A woman, aged 46, unmarried.

As far as can be ascertained, no abnormality was noted during the first five years of life. When the patient was 5, her mother died suddenly from heart disease, whereupon her grandfather had the patient medically examined ; her heart was said to be weak and she was put to bed for a month. Shortly after this she had scarlet fever and then diphtheria, and was very ill with the latter. At school she was short of breath and was unable to run ; she remembers that her face was highly coloured, and that she was repeatedly off school for a week at a time. After leaving school she did office work for seven years ; she occasionally had to take an afternoon's rest, but was seldom off for longer. For the next few years she was at home, and enjoyed fairly good health, but suffered from " slight attacks of breathlessness and dizziness " from time to time. In 1930 she underwent an operation for strangulated hernia.

In 1934 she was admitted to hospital. She had " felt seedy " on the previous day, and on going to bed became breathless and dizzy; nevertheless she was able to get up and go out shopping next morning; on her way home, she called on a doctor who sent her to hospital, where she remained for ten days. At that time she was described as well nourished, very highly coloured, and with slight cyanosis. The heart was enlarged. There was a loud blowing systolic murmur all over the præcordium and conducted to the axilla; the sounds were well heard in addition to the murmur, and the first sound was reduplicated at the apex. The pulse rate was usually 46, never less than 44, and only once as high as 50 during her stay in hospital. A cardiogram showed complete auriculo-ventricular block with an auricular rate of 60 and ventricular rate of 45·6; in lead I, the P waves were upright, but QRS and T were completely inverted; in leads II and III the complexes were normal. There was no polycythæmia, the red cell count being 4,760,000 and hæmoglobin 95 per cent. There is no record of the X-ray findings and the films are no longer available.

In 1936 she took work as a housekeeper, a job which she still retains. It was at this time, at the age of 40, that she began to feel more breathless and found she was becoming more blue. She noticed that her hands were blue, whereas hitherto the high colour was confined to the face. She could walk smartly for short distances without dyspnœa, but could not go far. At her work, she had to sit down and rest from time to time, but she had not had to go on the sick list. Within the last few months she has had a harsh cough from time to time, and has been hoarse for a day or two at a time; some two or three months ago she had a blood-stained spit, and recently the spit has on occasion been slightly streaked with blood. She has never fainted, and she has never had anything resembling a Stokes–Adams attack.

Examination. She is a small, underdeveloped, thin woman with a slight scoliosis. There is intense injection of the malar regions with small venules visible, the colour being a reddish violet ; in addition to this, there is cyanosis of the lips and hands. The heart is considerably enlarged, the apex being in the mid-axillary line, six and a half inches from the mid-line. The first sound at the apex is loud and accompanied by a soft blowing murmur; the second sound is reduplicated. The murmur can be followed medially for a short distance, but not further than the mid-clavicular line; there are no murmurs elsewhere. The pulse was 48 and regular, save for an occasional extrasystole. Blood pressure was 124/80 in February and 114/74 in September, 1942. The lungs showed generalized bronchitis in February, but were clear in September. There was albuminuria, but neither enlargement of the liver nor œdema.

The electrocardiogram (Fig. 1), substantially unchanged since 1934, shows complete auriculo-ventricular block with an auricular rate of 68 and a ventricular rate of 46. The auricular complexes are upright in all leads; the ventricular complexes (QRS and T) are inverted in lead I, resembling those seen in dextrocardia.

FIG. 1.—Electrocardiogram showing complete heart block and changes somewhat similar to those found with dextrocardia.

Skiagrams of the heart in the antero-posterior and oblique positions are shown in Fig. 2–4. The report on screening (Dr. J. G. McWhirter) is as follows :—" The transverse diameter of the cardiac shadow is increased beyond normal limits and the appearances suggest that this is due to right ventricular hypertrophy. The main branches of the pulmonary artery are enormously dilated and pulsation is easily seen in them. The main pulmonary artery is large and is easily seen in the right oblique position causing some indentation of the œsophagus. The lower end of the œsophagus is also displaced backwards and to the right by an enlarged left auricle. The aortic knob is not visible in the anterior view and in the left oblique position the aortic window is obscured by the large pulmonary vessels. The appearances are those of atrial septal defect. There is scoliosis of the dorsal spine."

The patient is active in her movements and walks very smartly without dyspnœa or visible increase in cyanosis; but she says that if she tries to walk any distance she becomes breathless. When she reported back in September, 1942, she had a harsh brassy cough and hoarseness, which suggested the possibility of a recurrent laryngeal nerve paralysis; but laryngoscopic examination (Dr. T. O. Howie) showed a simple laryngitis with congestion of the cords, and no evidence of paralysis.

DISCUSSION

There can be little doubt, in the first place, that this patient's heart block is congenital, and in the second place that she has an atrial septal defect. The ventricular rate of 46 points to a congenital as opposed to an acquired block; the ventricular complexes resembling those found in dextrocardia are equally suggestive of a congenital lesion. The increasing cyanosis in later life and the gross distension of the pulmonary artery and its main branches without congestion of the periphery of the lung fields are features described by Bedford, Papp, and Parkinson (1941), as characteristics of atrial septal defect.

There is one respect in which the skiagrams of the present case differ from those published by Bedford, Papp, and Parkinson in their series, and from those of two cases of atrial septal defect seen by the author. Prominence of the conus in the antero-posterior view is a usual feature in cases of *A.S.D.*, but is absent in the present case. The contour of this patient's heart in the antero-posterior view resembles that of a case of ventricular septal defect with congenital block published by Stein and Uhr (1942); their case, however, lacks the distension of the pulmonary artery branches. Gross enlargement of the pulmonary artery is stated by Bedford, Papp, and Parkinson to be most exceptional in isolated ventricular septal defect; and they report that bulging of the pulmonary arc was absent in one of their cases of *A.S.D.*, which showed a rounded left border, while another showed a straight left border comparable with that of mitral stenosis.

FIG. 2.—Teleradiogram in antero-posterior position, showing enlargement of the heart and of the pulmonary artery.

FIG. 3.—Teleradiogram in right anterior (I) oblique position, showing a large pulmonary artery and backward displacement from a large left auricle.

FIG. 4.—Teleradiogram in left anterior (II) oblique position, with the aortic window obscured by the large pulmonary vessels.

The cause of the block in this case is thought to be a concomitant ventricular septal defect. The combination of atrial septal defect with ventricular septal defect is not uncommon; and although complete block is rare with atrial septal defect (it was present in none of Bedford, Papp, and Parkinson's cases) it has been described (Taussig *et al.*, 1938). The diagnosis of ventricular septal defect was, in fact, suggested at the time of her admission to hospital in 1934 on the grounds of the character of the murmur and the electrocardiographic findings.

The absence of the characteristic " bruit de Roger " at the present time could be explained in two ways. First, a fall in pressure in the left ventricle with a rise in right ventricular pressure may have equalized the pressure on the two sides with consequent disappearance of the murmur. Alternatively, its disappearance may have been brought about by rotation. Bedford, Papp, and Parkinson have shown that in *A.S.D.* there is progressive enlargement of the right ventricle which comes to form the apex and displaces the left ventricle backwards; rotation of the ventricles in this direction might well displace the murmur of a ventricular septal defect towards the left, that is to say towards the apex, where a systolic murmur is still audible in the present case.

The electrocardiographic features are curious; while the auricular complexes are upright in all leads, all deflections of the ventricular complexes are inverted in lead I. The ventricular complexes (but not the auricular complexes) are identical with those found in dextrocardia. The only other condition in which inversion of TI may be associated with an apparent right axial deviation is the QTI type of coronary thrombosis, a possibility that does not arise in this case. Apart from the conditions mentioned, I have never seen TI inversion resulting from simple right axial deviation without inversion of TII and TIII. Bedford, Papp, and Parkinson, however, record it in two of their cases of *A.S.D.* It is suggested that this feature of the cardiogram may also be due to rotation; with sufficient enlargement of the right ventricle towards the left and consequent displacement of the left ventricle backwards and towards the right, the interventricular septum will also be rotated clockwise; a ventricular electrocardiogram resembling that of dextrocardia might well be produced in this manner.

Summary

A case of atrial septal defect with ventricular septal defect and congenital complete heart block is described and discussed. She had fairly good health until she was 40, and was still working as a housekeeper at 46 years of age.

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CONGENITAL COMPLETE HEART BLOCK

BY

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Few of the reported cases of congenital complete heart block have been over twenty years of age. It seems, therefore, worth reporting seven cases who are in good health at various ages between 22 and 42 years. This ætiological factor should, therefore, be thought of in middle-aged and even in elderly patients with complete heart block of unknown ætiology.

Campbell and Suzman (1934), reporting eight cases, suggested that " when patients have been followed for a longer time they may be found in good health at a more advanced age." Of the eight cases reported in 1934, one had died and one was then only 3 so would still be a child; the remaining six, who were then between 12 and 33 years of age, and another man of 29, who was seen soon after, have been followed up; all have been traced and found to be leading ordinary lives without trouble from their hearts. This paper is not concerned with a clinical description of their condition which has been given already. It is an attempt to assess their capacity for leading a normal active life during the nine years that have elapsed since they were reported. The first six are given the same case numbers as in the previous paper; the seventh (Case 9) has not been reported previously.

Case 2. The diagnosis was made when she was 1 year old. She was under observation at the Heart Hospital from the age of 12 to 19 years. She was then a fit normal-looking girl, free from symptoms, and working as a shorthand typist. Her heart was a little enlarged and she was thought to have a patent interventricular septum.

Four years later she was examined at a routine visit and the condition of her heart was unchanged. A year later she had pleurisy; she did not feel ill for long and had little cough, but after some weeks' observation was diagnosed as early tuberculosis of the lung. She was in bed for two months and off work for six months, and six months later (with medical approval) married. This was shortly before the war. Since then, except that she has been " bombed out " of her home, she has led an uneventful life and kept in good health.

She is now 28 and does her normal household duties and feels less tired than when she was doing regular office work. She states that she cannot do heavy work without feeling unduly tired, but this has always been the case; recently to the surprise of herself and her friends she has been able to do all the heavier work connected with re-starting her London home.

Case 3. The diagnosis was made when he was 2, and confirmed at his school medical examination at 6 years old. He was under observation at the Heart Hospital at the age of 12 years. He was leading a normal life except that he had not been allowed to play games at school. The heart was just enlarged, and he was thought to have a slight interventricular septal defect.

After school he worked as an electrician and kept in good health. Though he did not play football, he did a good deal of camping and swimming.

He is now 22, and has been 2 years in the R.A.F. He actually passed for flying duties, but has continued his ground duties as an electrician. He has not been to hospital and has had nothing except very minor ailments.

Examined recently while on leave, he looked fit. His heart rate was unchanged at 48, and his B.P. 130/85. The systolic murmur was not very obvious and I was less sure of the diagnosis of patent interventricular septum. The apex beat was forcible and just out to the left. Radioscopy showed a large left ventricle with a very forcible beat and some prominence of the pulmonary conus. In proportion, his heart had certainly not become larger—the maximum transverse diameter in 1932 being 10·9 cm. in a chest of 20·4 cm.; and in 1942, 11·6 cm. in a chest of over 23 cm., which is some evidence, I think, that his work has not been too strenuous. He said he was a little breathless when there was specially heavy work, but was otherwise able to do everything in the same way as the others.

Case 4. Here, too, the diagnosis was made at the age of 2 years, and he was the only patient in the series with a clear history of Stokes-Adams attacks, frequently from the age of 2 to 4 and occasionally up to 8. He then got on well and was under observation at Guy's Hospital from the age of

12 to 16 years. His heart was slightly enlarged, the rate was generally about 42, and there were signs of a patent interventricular septum.

His story since his case was last reported is as follows. He started work at 16 as a baker's van boy, and though the work was light, the Stokes-Adams attacks recurred after a year. He took as much rest as he could without reporting sick, and changed his work to a hairdresser's apprentice. Here he kept quite fit for a year and gradually resumed cricket, football, and swimming. He then, at 18, started work in a garage and though it was heavy work felt very fit and got on well. At 21 (1938) he went into an aircraft factory and also indulged in cycling, dancing, and gymnastics, and had almost forgotten that there was anything the matter with his heart till long hours and hard work after the war had started made him feel it again. In spite of this he carried on and joined the Home Guard and acted as a fire watcher in his factory until January, 1941, when he again had a recurrence of his Stokes-Adams attacks. He took three weeks' rest in bed, again asking no medical advice, and changed his work, becoming a machine shop foreman where he managed well and had no further attacks (September, 1942).

He is now 25 and has done extremely well, working hard in many jobs and playing cricket and football, and since the war taking his full share in the Home Guard, firewatching, etc. He has without doubt done much more than he should, and I have advised him to take his heavier duties as easily as possible. I have given this story fully, because so often it is lack of courage rather than bodily disability that is responsible for the refusal to work hard and to face difficulties.

Case 5. Here, too, the diagnosis was first made at the age of 2 years. She attended the Heart Hospital for six months when she was 27 years old and, until that time, had easily been able to cycle 40 miles a day. Her heart was a little enlarged, the rate was from 46 to 50, and there were signs of a patent interventricular septum. Six years later, when she was 33, she was doing ordinary housework on a farm and was also walking two miles a day to her work without any real discomfort.

She is now 42 and writes that she has kept well and continued the same work, and that she has needed no medical attention of any sort for the last 15 years (August, 1942). So far as I am aware, this and the patient of Peel (1943) are the oldest cases of congenital complete heart block reported.

Case 7. The diagnosis was first made when she was 5 years old. She attended the Heart Hospital from the age of 20 to 22 years. She looked a very healthy girl and was leading a normal quiet life working as a hairdresser. She had never been allowed to play games and was somewhat short of breath on any special exertion. She came to hospital because of tiredness and of feeling faint and giddy, but there was nothing to suggest that she had Stokes-Adams attacks, and ordinary attacks of faintness were actually observed. The heart was full size and she was thought to have a defect of the interventricular septum.

She is now 31 and writes: "I have not been engaged in any regular occupation for several years with the exception of light household duties. But since the war I have been doing sedentary work with an optical firm and I have managed this all right, though at times it makes me tired. Apart from an occasional visit to my own doctor I have had no treatment for nine years."

Case 8. The diagnosis was first made when he was 13 years. He was under observation at Guy's

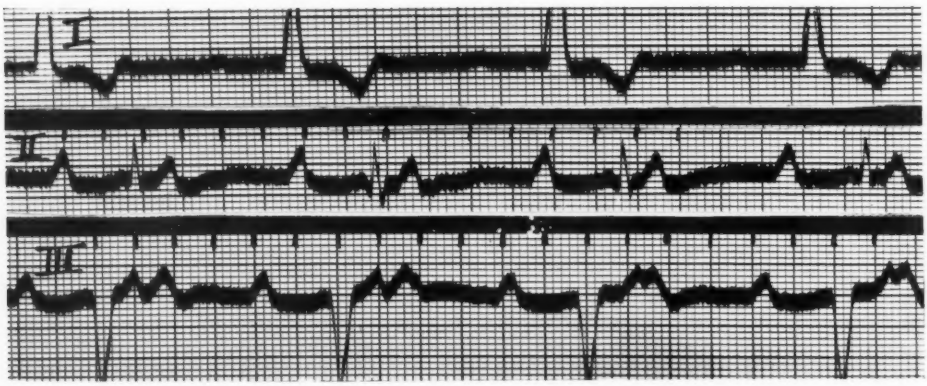

FIG. 1.—Case 8. The degree of heart block is probably complete, but it has the appearance of 2 : 1 block—a condition that is rare, if not unknown, in congenital cases—because the auricle is beating almost exactly twice as fast as the ventricle. The inversion of T in lead I has developed in the last ten years.

Hospital from then to 17 years, and felt well and was working in a bottling factory. His heart was slightly enlarged and he was thought to have a slight defect of the interventricular septum.

He was difficult to trace since the area in which he had lived was a waste of rubble as a result of enemy action. But by a curious coincidence he was attending Guy's Hospital at the time of this survey with a Colles' fracture sustained at work at Salisbury; he thought so little of his heart that he had not mentioned it at all.

He is now 26 and, though he was rejected from the army, has worked as hard as his mates, laying concrete floors for 54 hours a week, has played football in his club team, and has won several boxing matches. He has been regularly at work without medical attention for 9 years.

I have not been able to examine him, but have obtained a cardiogram which is shown (Fig. 1), because the signs of left ventricular preponderance with inversion of T in lead I, this last having developed since 1932 (see Fig. 13, *loc. cit.*), might suggest that it was associated with coronary atheroma or high blood pressure and not congenital; and also because it is suggestive of 2 : 1 heart block—a condition which I have not seen with congenital disease.

Case 9. *Not previously reported.* A dental surgeon, aged 29, came to see me in 1935 because his slow heart rate had led to difficulties about life insurance. His only recent illness had been a rather severe attack of migraine six months before, with vomiting, faintness, and hemianopia; he had reduced his cigarette smoking and there had been no recurrence.

His heart rate was generally between 36 and 42 and the electrocardiogram confirmed complete

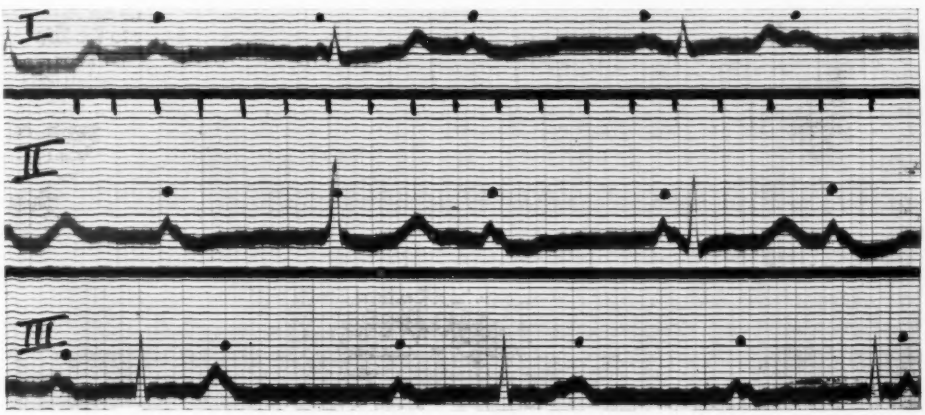

FIG. 2.—Case 9. Congenital complete heart block in a man of 29 with few symptoms. Auricular rate 80; ventricular rate 36; this could easily be increased to 50 after exercise.

heart block without any other abnormality. The heart was full-sized or a little enlarged to the left (max. trans. diam. 11·5 cm. in a chest of 21·5 cm.) with a rounded left ventricle. There was a systolic murmur, loudest half-way between the apex and the mid-line, which was thought to indicate a patent interventricular septum, though it was softer than in most such cases. The blood pressure was 125/80 and no other abnormality was found. The heart rate quickened a little with exercise, rising from 18 in the half-minute before to 27 and 23 in the first two half-minutes after a simple stepping exercise (18 steps a minute for 3 minutes).

The diagnosis of complete heart block had not been made at an early age so as to make it certain that this was congenital, but there was no history of rheumatism or diphtheria or of other serious illness, and he had seen Dr. R. O. Moon in early childhood because there was some question about his heart being enlarged. His mother remembered the heart was then said to be slow and that the doctors always seemed very interested. Dr. Moon wrote that he had never found anything to suggest rheumatic or other inflammatory disease and that after keeping him under observation for some time he had allowed him to ignore it, and that he thought the diagnosis now made was probably correct, though he had no notes available to confirm the actual rate of the pulse.

I advised that he should lead a normal life and that he should be accepted for life assurance with a small extra. It is interesting that as a student at Guy's he remembered being admitted to hospital with jaundice and being demonstrated as a case of bradycardia due to this, showing how readily congenital heart block may be overlooked.

He is now 36 years of age, feels quite fit and leads a normal life, practising as a dentist, cycling (since the war), and gardening. His pulse rate is generally between 35 and 40.

One other new case, though not of interest from the present point of view, may be mentioned because of the post-mortem finding of a patent foramen ovale without any patency of the interventricular septum.

Case 10. A girl, aged 8 months, was admitted under Dr. E. C. Warner for severe malnutrition. She was short of breath, even feeding, and the heart was enlarged, with the rate between 48 and 60. A diagnosis of congenital complete heart block was made and she was sent to see me. The diagnosis was confirmed by a cardiogram (auricle, 114; ventricle, 44), which was normal otherwise. There was thought to be a patent septum on the evidence of a systolic murmur.

She died a few weeks later and Dr. Warner wrote that the heart was much enlarged with collapse of the left upper lobe of the lung. There was a large patent foramen ovale, but no visible abnormality in the interventricular septum or elsewhere in the heart, which unfortunately was not kept.

Probably, some of the elderly patients with complete heart block of unknown ætiology are in fact congenital cases that have not been recognized, partly because the pulse is generally not nearly as slow as with acquired heart block. The following case might perhaps be of this nature though the evidence is very incomplete.

She was first seen by me when she was 65, with symptoms of intestinal obstruction. She had led a semi-invalid life for 20 years. She had no cardiac symptoms, but the heart rate was 40 due to complete heart block. There were no murmurs, no rise of blood pressure (130/80), no more arterial thickening than might be expected at her age, and only slight enlargement of the heart to the left.

Twenty years before she had an unfortunate partial colectomy, followed two years later by an operation for partial obstruction and subsequently by two attacks of intestinal obstruction due to volvulus. Her weight was 4 st. 9 lb. and had not been above 6 st. since the first operation. She was relieved of this attack but died a year later with intestinal obstruction.

Her doctor wrote that during the 7 years he had known her the heart rate had always been slow, and that he thought it had always been slow as all the doctors for the past 20 years had remarked on it. He also reported that one of her brothers had a slow pulse.

This history only takes her heart block back till she was 45, but as it was symptomless and found by chance it may well have been there before, for if it had been due to coronary disease something more would probably have been found after 20 years. The rate of 40 is slower than in many congenital cases, but the idiopathic ventricular rate may perhaps become slower as the patient gets older.

Summary and Conclusions

The present condition of seven cases of congenital complete heart block, now aged 42, 36, 31, 28, 26, 25, and 22 is reported shortly. Full details about six of them were published nine years ago. All these six and one other (first seen shortly after the paper was published) have been traced—a very satisfactory result after this interval of nine years, especially in war time.

All are alive and well, and their degree of activity could be taken as a fair cross section of the general public. Of the four men, two are working men, who though rejected from the army have led strenuous lives, both in their work and in their play—almost certainly doing more than they ought to as their hearts are not normal. One has been two years in the R.A.F. and has been passed for flying duties, and the fourth is a professional man who leads a normal life with gardening and cycling in his spare time.

Of the three women the eldest does ordinary housework on a farm, but the other two lead rather more sheltered lives, possibly because their doctors have discouraged them too much. One was at easy work till she developed tuberculosis a year before her marriage, and the other after doing light duties at home for six years has taken up sedentary work since the war. Except for the one case of tuberculosis, no unexpected developments have arisen in any case, and the one who had Stokes-Adams attacks in infancy has led the most strenuous life with only two short periods of recurrences.

Congenital complete heart block is not rare. It is overlooked because the rate is relatively fast, about 40–56, and also because the possibility is not remembered.

If there are no special complications carrying special risks of their own, the prognosis is good, and it will probably prove that the condition is compatible with survival to old age.

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TUBERCULOUS PERICARDIAL EFFUSION

BY

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Tuberculous pericardial effusion is not common; and so the case described is of interest on account of the patient's age, the frequency with which the pericardial effusion required tapping, the relative absence of symptoms during most of the illness, and the stages through which the case passed from gross effusion to relative dryness at autopsy with only about 2 oz. of fluid in a greatly thickened pericardium.

Description of Case

A sailor, aged 23, was admitted into a hospital on August 16, 1940, for epigastric pain and frequent vomiting, which had begun three days previously. There had been a similar attack three months previously. There was continued pyrexia up to 102. The diagnosis was apparently difficult until he complained of some sub-sternal tightness a few days later, when attention was directed to his heart. This was found to be enlarged, 1 inch outside the nipple line, but it was only after an X-ray that the diagnosis of pericardial effusion was established. Before this, on account of dullness at the left base of the lung with diminished breath sounds, a pleural effusion was suspected, but the X-ray did not confirm this. The blood pressure was typically low, 100/70.

Repeated tappings were performed as under:

August 23, 300 c.c. ; *August* 27, 400 c.c.; *August* 30, 500 c.c.; the fluid each time being sterile and clear and straw-coloured; *September* 6, 300 c.c.; and *September* 13, 550 c.c., the fluid being deeply blood-stained on these two occasions. (For later tappings see below.)

On Sept. 16 he was admitted to the Southern Hospital, where he came under my observation. The heart was greatly enlarged, both to left and right. The heart sounds were faint and muffled. Continued pyrexia was still present, varying between 99 and 103. Symptoms were absent, except for sub-sternal tightness which he seemed to experience whenever the effusion increased; this was relieved after tapping. Tachycardia was a constant feature throughout, the pulse rate being about 100 to 120. The blood sedimentation rate was 78 mm. after one hour. Blood culture was sterile. A Mantoux test (1 in 10,000) was negative. And in spite of a negative guinea-pig test on two occasions, the diagnosis of tuberculous pericardial disease was made.

September 24, aspiration of 520 c.c. of old blood-stained fluid. There was no change in his blood pressure, 105/80, before and after, or in the cardiogram which showed the characteristic T wave inversions.

November 6, aspiration of 600 c.c. of fluid, less blood-stained. He had remained fairly comfortable and without sternal pain. On this occasion an air replacement was done, and an X-ray afterwards showed the parietal layer of the pericardium, which measured half an inch thick. The cardiac shadow was not diminished after the tapping. X-ray on December 10, showed the air replacement to be absorbed, and an increase in the size of the effusion. A course of sulphapyridine (17 g.) was given about this stage, and brought down the temperature for a time. Towards the end of December he developed a dry cough and the temperature rose again to 102. He began losing weight and he had night sweats.

December 28, aspiration of 600 c.c. of amber-coloured fluid ; air replacement of 100 c.c. Fine crepitations were now heard, and an additional diagnosis of miliary tuberculosis of the lungs was made. He gradually became worse about the middle of January 1941, and was mildly delusional at times. On January 19, 1941, he became drowsy; coma set in and he died the next day.

Post-mortem examination. Pleura: light fibrous adhesions, obliterating both pleuræ.

Heart: Great dilatation of the pericardial sac, which contained only 2 oz. of amber fluid, but was much thickened by granulomatous tissue. A layer of friable yellow fibrin, uniting the thickened layers of the pericardium, up to 1 cm. thick; no loculations. Heart itself only slightly enlarged; valves normal.

FIG. 1.—Radiogram of the heart showing much dilatation of the pericardial sac.

Lungs: Congested and closely studded with granulomatous miliary tubercles; no cavities. Caseous glands in both hila and at the bifurcation of the bronchi, two inches by one quarter inch in size on each side.

Liver: Cloudy swelling and a few miliary tubercles.

Spleen: Three times normal size; some tubercles.

Kidneys: Cloudy swelling with streaks of pus in the pyramids; studded with miliary tubercles.

Bladder: Infected with pus.

Prostate: Caseous tuberculosis present.

Brain: General œdema. Sero-meningitis over the base of the brain with a few scattered tubercles in the fissures. A tuberculoma, 0·5 cm. in diameter, in the left occipital cortex.

Histological examination confirmed tuberculosis.

DISCUSSION OF CASE

There is no doubt that in this case the primary focus was a tuberculous gland in the mediastinum, secondarily affecting the pericardium. And later as the disease progressed, further dissemination occurred, causing generalised miliary tuberculosis. Another point of interest was the absence of lung symptoms until the final phase of his illness. Hæmorrhagic pericardial effusions are said to be characteristic of tuberculosis. I think this is an open question, and the probability of trauma when needling must be taken into full account. In this case the first three tappings were not blood-stained. The next two were deeply blood-stained, and the succeeding ones clearly pointed to the presence of old blood in the sac. The last specimen of pericardial fluid was only amber-coloured.

Another point of interest is that the cardiac shadow did not diminish after paracentesis, owing to the very thick and rigid pericardium.

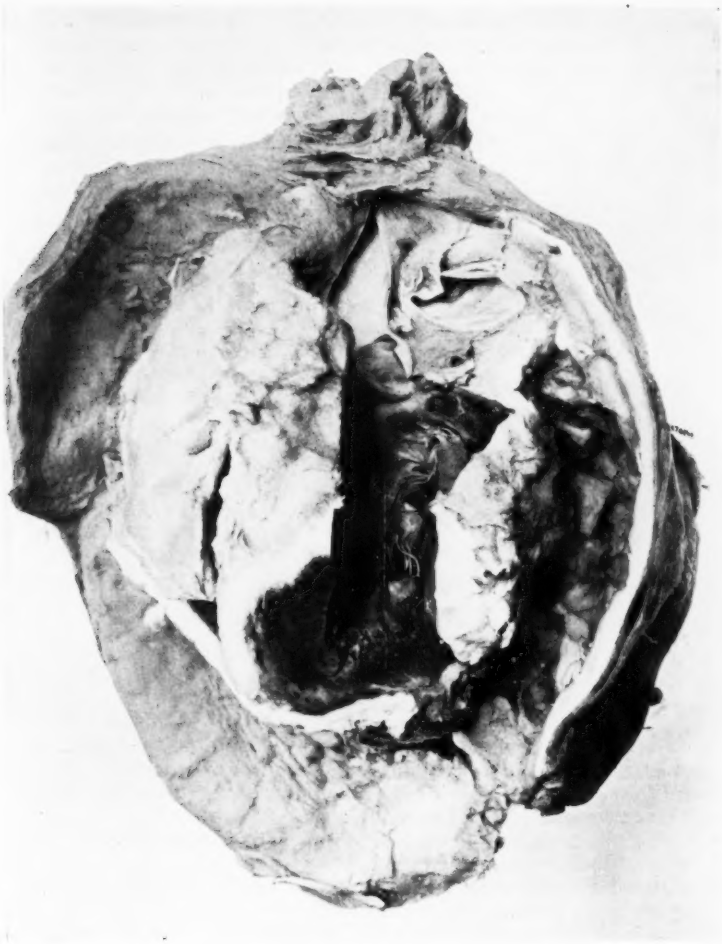

FIG. 2.—Photograph of the heart showing much thickening of the pericardium.

The negative results of laboratory findings, such as the absence of tubercle bacilli in the fluids and the failure of inoculation of guinea pigs to produce any result, should also be stressed.

POST-MORTEM STATISTICS AT GUY'S HOSPITAL

To assess the incidence of tuberculous pericarditis I have analysed 1893 autopsies at Guy's Hospital from January 1935 to June 1939. There were 102 tuberculous cases with lung involvement. There were 6 cases of tuberculous pericarditis, confirmed by histological section; 2 others with pericarditis were most probably tuberculous, judging from the post-mortem description, but cannot be included as there was no mention of tuberculosis macroscopically or microscopically. There was also one case of myocardial tubercle alone, without pericardial involvement. This makes an incidence of 0·3 per cent of all the cases that came to autopsy during this period, and 6 per cent of all cases that had tuberculous involvement in any organ. If the two probable cases were included it would raise the incidence among general cases only to slightly over 0·4 per cent, but it would raise the incidence among tuberculous cases to as high as 8 per cent.

As a comparison for incidence, Kornblum, Bellet, and Ostrum (1933) give figures of 1 per cent among general cases and 4 per cent among tuberculous cases (Philadelphia Hospital) : they reported 17 cases during a period of two years. The incidence of tuberculous pericarditis among non-

Europeans in South Africa appears to be much greater than in the Guy's Hospital series; Heimann and Binder (1940) reported on 31 cases over a period of 14 years, which gives an average of over 3 cases a year. This contrasts with 1·3 cases a year at Guy's Hospital, and 8·5 cases a year at the Philadelphia Hospital. The number of autopsies is not mentioned in either instance.

Of the 6 cases, only one was diagnosed as such during life, the remainder being post-mortem findings. (The case described in this paper does not belong to this series.) In the remaining 5 the tuberculous pericarditis was a complication of some other disease. In all instances except in Case 3, the mediastinal glands were tuberculous.

Case 1. Male, aged 43. Myelogenous leukæmia. Post-mortem confirmation. Clusters of large yellow tubercles radiating outward to the hilar lymph glands which were caseous. Caseous nodules in lungs. Visceral and parietal layers of the pericardium covered by fibrinous exudate and studded with tubercles. Sac containing 300 c.c. of clear yellow fluid.

Case 2. Male, aged 70. Died on arrival at hospital from hæmorrhage from the lungs. No other clinical history.

Post-mortem: Lungs adherent to pleura. Surface extension of miliary follicles in the sub-pleural lymphatics. A reactivated Ghon focus in the left lower lobe. Mediastinal glands tuberculous. Pericardial sac thickened by recent lymphatic extension of the miliary type from the adjacent pleura. Light fibrous adhesions between both layers of the pericardium ; no exudate.

Case 3. Male, aged 56. Syphilitic aortic incompetence with pleural effusion. Died two months after admission from cardiac failure.

Post-mortem: In addition to the widened syphilitic aorta, a left-sided pleural effusion of clear fluid. Two loculated empyemas in the right pleural cavity, their walls consisting of tuberculous granulation tissue. External surface of the pericardium covered with a delicate fibrinous exudate. Both layers moderately adherent and covered by a thick yellow granular fibrino-purulent exudate. No evidence of any tuberculous lesion in the lungs. Mediastinal glands likewise not affected by tubercle.

Case 4. Female, aged 4 months. Admitted for meningitis.

Post-mortem: Miliary tuberculosis of all the organs. Mediastinal glands caseous, with a caseous focus in the right upper lobe of the lung. Pericardium, miliary tuberculosis; no effusion.

Case 5. Male, aged 23. In hospital for over two months, and treated for increasing cough, pain in the chest, and later for pleural effusion. Sputum always free from tubercle bacilli. Pericarditis one month before death. The patient gradually went downhill and died. Ten months previously he had begun to have symptoms of lassitude and anorexia.

Post-mortem: Right lung studded with miliary tubercles. A fibro-caseous empyema, only 2 or 3 weeks old, in the lower third of the right pleural cavity. On the left side a much older thick walled empyema. Mediastinal glands caseous. Pericardium universally adherent owing to tuberculous pericarditis of considerable duration, caseating freely. Heart not enlarged. A large caseating nodule attached to the free border of the marginal cusp of the mitral valve. Section showed that the pericarditis was of many weeks' duration.

Case 6. Male, aged 14. Admitted three months before death on account of cough, dyspnœa, cyanosis, and pleural and pericardial effusions. Both cavities tapped once; clear fluid drawn off containing many lymphocytes. Tuberculous pericardial effusion diagnosed clinically, and injection into a guinea pig confirmed this by producing a tuberculous lesion. Later on, headaches and meningitic symptoms, followed quickly by the patient's death.

Post-mortem: Bilateral pleural effusions containing clear fluid. Old and recent pleurisy on both sides. A great deal of sub-pleural miliary tubercle. No evidence of any tuberculous lesions in the lung substance. Mediastinal glands caseous. Pericardial sac enormously thickened, only slightly adherent to the lungs, and containing much granulation tissue; easily broken down adhesions between the two layers of the pericardium. Heart of very small size. Section showed that the disease process was of considerable age. This was the only one of the six cases that was diagnosed as having tuberculous pericarditis during life.

Discussion of Autopsies

An interesting fact brought out by the analysis of the 1893 cases was that of the 102 with tuberculosis there were 27 with an excess of pericardial fluid alone, without any macroscopic evidence of pericardial disease; the amounts varied from slight excess to 200 c.c. of fluid. I feel that if sections were examined in these cases there would be microscopic evidence of miliary tubercle of the peri-

cardium. Obviously this point is of academic rather than of practical interest as all these 27 cases died from their primary tuberculous lesions. Thus 26 per cent of the tuberculous cases had some excess of pericardial fluid. A comparison with 202 consecutive autopsies was made as to the frequency of excess pericardial fluid in 41 primary cardiac cases; 13 had excess of fluid (32 per cent). There were also 13 tuberculous cases in this small series, 3 of which had excess of fluid, the proportion happening to agree well with the 1893 cases which were analysed.

Of these 41 cardiac cases, 10 had rheumatic valvular disease and 12 had high blood pressure. 5 of the 10 in the rheumatic group (50 per cent) had excess pericardial fluid and 4 of the 12 (33 per cent) in the hypertensive group had excess fluid.

In the 1893 autopsies, only 14 cases of hæmopericardium occurred, and of these 14 cases only 1 was of tuberculous pathology. In this one the epididymis, prostrate, meninges, and lungs were affected; there was nearly 4 oz. of bloody fluid in the sac; the pericardium was normal to naked eye, but it was not sectioned. The remainder consisted of 8 cases of rupture of the myocardium following cardiac infarction ; 1 case of rupture of a dissecting aortic aneurysm, 3 cases of carcinomatosis, and 1 case of high blood pressure with a cerebral hæmorrhage.

Summary

A case of tuberculous pericarditis is described. It is suggested that in any obscure case of pericardial effusion, especially where this is large, tuberculosis should be thought of as a possible diagnosis; and that this is still more likely if tapping has to be repeated.

Among 1893 consecutive autopsies there were 6 cases of tuberculous pericarditis, but only one of these had been diagnosed clinically. Hæmopericardium did not occur in any of these cases. Some excess of pericardial fluid was found in about a quarter of all the tuberculous cases.

I would like to thank Dr. Willis for his kindness in performing some of the pericardial tappings, and Dr. Alan Daly for his permission to publish this case.

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SIGNS SIMULATING THOSE OF MITRAL STENOSIS

BY

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Duplication of the second heart sound at the apex, especially when this is associated with a systolic murmur, is apt to be regarded by recruiting medical boards as evidence of an organic mitral lesion. The purpose of this paper is to suggest that this sign is physiological, and to put forward a hypothesis to account for it and for certain other signs that are apt to lead to a mistaken diagnosis of mitral stenosis. In a group of 835 recruits referred to the writer by medical boards of the Ministry of Labour and National Service, a duplicated second heart sound at the apex was heard in 157; this series does not include any case in which an early diastolic murmur would be heard or a presystolic murmur could be elicited by exercise.

The duplicated second sound, like the presystolic murmur of mitral stenosis, is best heard with the patient lying on his left side. As it seemed probable that this was due to the change in the axis of the mitral orifice with change of posture, the writer sought the help of Professor Wood Jones, who kindly examined a series of cadavers hardened in formalin and found that, relative to the long axis of the body, the blood stream issuing through the mitral orifice was directed mainly forwards with an inclination of about 20° downwards and slightly towards the left. Thus, with the patient lying on his back, the blood stream is flowing almost directly against gravity, whereas when he turns on his left side it is flowing horizontally. The latter position would tend to accelerate the blood flow from auricle to ventricle, and so, as will be shown later, would render conditions more favourable for duplication of the second heart sound.

The second element of the duplicated second heart sound follows the closure of the semilunar valves by about 0·1 sec. It therefore corresponds in time to the physiological third heart sound; in fact the two appear to be identical. Thayer (1908) found that a third heart sound could be heard in 65 per cent of healthy young persons. He also demonstrated, experimentally in dogs, a similar sound which corresponded in time to the sudden distension of the ventricle that occurs early in diastole, and he suggested that the third heart sound was due to sudden tension of the A-V valves produced by the first rush of blood from auricle to ventricle.

The physiological third heart sound is much more commonly heard in young than in older subjects. The same is true of the duplicated second sound in recruits. Table I gives the age incidence of the 157 cases in the present series as compared with the age incidence of the whole group of 835 cases among which they occurred.

TABLE I

AGE INCIDENCE OF DUPLICATED SECOND SOUND

Age	Whole group	With duplicated second sound	
		Number	Percentage
Under 20	228	96	43
Over 20	604	61	10
20–24	84	13	14
25–29	151	20	13
30–34	164	17	10
35–39	136	10	7
Over 39	69	1	1
Not stated	3		
Total	835	157	19

From this table it will be seen that whereas the incidence was 19 per cent in the whole group, it was 43 per cent in men under twenty as compared with only 10 per cent in men over that age.

Most of these young men appeared to be perfectly fit; some were athletic and many were well above average physique. In the opinion of the writer, 70 per cent were fit for Grade I, and of the 46 cases placed in lower categories, 22 were lads of eighteen or nineteen whose physical development was in arrear of their age. They were accordingly temporarily placed in Grade II or III. Thirteen only were down-graded on account of permanently poor physique, and 11 for other reasons.

So far as pulse rate and systolic blood pressure are concerned there was remarkably little difference between recruits with a duplicated second sound and the entire group of which they formed part. In both cases the mode for the systolic pressure was 130–140. Only 10 per cent of the recruits with a duplicated second sound, however, had a diastolic pressure over 80 as compared with 22 per cent in the entire group. This is not unexpected in view of the lower average age in the former group.

Only a few of the electrocardiograms exhibited right axis deviation, but in most cases radioscopy did suggest that in men with a duplicated second heart sound the pulmonary arc was more prominent than usual, the heart conforming to the childish contour. William Evans (1942), whose observations were based on actual measurments, came to the same conclusion.

In these recruits, the duplicated second sound is generally associated either with a frank apical systolic murmur or with an impure first heart sound; often it was this murmur which was responsible for the case being referred for a second opinion. It seems possible that this murmur is attributable to a safety-valve mitral incompetence, associated with overfilling of the ventricle, and is comparable to the murmur which one hears in normal people immediately after severe physical exertion.

The Presystolic Murmur

In endeavouring to assess the significance of the duplicated second heart sound and to determine the mode of its production, it is helpful to consider the incidence of the crescendo presystolic murmur of mitral stenosis. In the production of an obstructive murmur two factors are concerned, the size of the orifice and the velocity of the blood flow: the one is static, the other dynamic. No matter how small the orifice, a murmur will only be produced when the blood flowing through it attains a certain critical velocity. The importance of the dynamic factor is well illustrated by following patients with mitral stenosis through pregnancy. In many of these cases, a loud presystolic murmur is heard during the later months of pregnancy: but, after delivery, no murmur is audible at rest, though one can be elicited by exercise. In such cases, it is obvious that the presence or absence of a murmur is determined not by the size of the mitral orifice but by the velocity of the blood flow.

There is an inverse mathematical relation between the degree of stenosis and the velocity of the blood flow required to produce an obstructive murmur. When stenosis is considerable a murmur is heard at rest, but when it is trivial there is no murmur unless the rate of blood flow is increased by exercise. The following observations suggest that even when the mitral orifice is normal, an obstructive murmur may be produced if the rate of blood flow be sufficiently increased.

In the course of a routine examination of athletes at the Olympic Games in Amsterdam, Ellis and the writer (1931) found that, in certain perfectly normal subjects, the first heart sound might be so modified that it was indistinguishable from the presystolic murmur and accentuated first heart sound of mitral stenosis. This sign was present in 12 out of 192 athletes examined; three were Marathon runners, three long-distance runners, and three long-distance cyclists—all athletes whose particular form of sport entailed prolonged and severe exertion. It was not present in any of the 18 sprinters or 16 middle-distance runners included in this series. A similar observation was made by Sewall (1909), twenty years previously. His explanation was that when the ventricle is filled at a certain rate, the reflux of the blood current tends to bring the cusps of the mitral valve into approximation, so that the auricle, in expelling its contents, has to force a channel between them. This explanation is analogous to the Austin Flint hypothesis, but it seems undu ly speculative. An alternative explanation is that, in athletes who indulge in prolonged and severe exertion, the auricles share in the general cardiac hypertrophy that is known to occur. Consequently the velocity with which the blood is projected into the ventricles by the hypertrophied auricles is greater than under normal conditions, and the mitral orifice proves relatively too small for the increased rate of blood flow.

Further evidence in support of this hypothesis is derived from the fact that in many cases of acute thyrotoxicosis the first heart sound bears a distinct resemblance to that of mitral stenosis. In 1914 Bridgeman demonstrated in graphic records of the normal first heart sound a series of small vibrations synchronous with auricular systole. These were of such low intensity that they failed to reach the threshold of audibility. Amplification of these presystolic vibrations, sufficient to render them audible, accounts for the roughening of the first heart sound in thyrotoxicosis (Bramwell, 1935). A

similar modification of the first heart sound is liable to occur in any excitable overacting heart and may lead to a mistaken diagnosis of mitral stenosis. This mistake is not surprising; for, if the hypothesis outlined above be correct, there is no auditory line of demarcation between anatomical stenosis due to a narrowed orifice and physiological stenosis due to an increased rate of blood flow. The one is absolute; the other, relative.

The Early Diastolic Murmur

To revert to consideration of the significance of the duplicated second heart sound at the apex, the diastolic part of the heart cycle may be divided physiologically into three phases in accordance with the velocity of the blood flow from auricle to ventricle. When the mitral valve opens, the pressure in the auricle is much higher than in the ventricle, and the blood which had been accumulating behind the closed valve during systole rushes in a swirling torrent into the empty ventricle. As soon as the initial difference in pressure between the two chambers has been relieved, the rate of blood flow from auricle to ventricle diminishes and the torrent is converted into a quietly flowing stream. Finally, when the auricle contracts, the rate of blood flow through the mitral orifice is again increased.

In extreme stenosis a rumbling murmur is heard throughout diastole, but in slight stenosis it is only during early diastole and presystole that the velocity of blood flow is sufficient to produce a murmur, the intermediate phase of diastasis being silent.

The fact that, in the lesser degrees of mitral stenosis, a presystolic is more common than an early diastolic murmur suggests that the difference in pressure on the two sides of the mitral orifice is greater during auricular systole than during early diastole. This may be due to the fact that in old-standing cases of mitral stenosis, left auricular hypertrophy is the rule, and the force with which the blood is ejected by the auricle is correspondingly increased.

The classical signs of slight mitral stenosis are a presystolic murmur with an accentuated first and a duplicated second heart sound. When stenosis is more pronounced the duplicated second sound is followed by a diastolic murmur, the duration of which varies with the degree of stenosis.

The second element of the duplicated second sound in mitral stenosis is called by French cardiologists " le claquement d'ouverture de la mitrale " and ascribed to vibrations of the thickened mitral valve set up by the first rush of blood from auricle to ventricle. In this respect its mode of production is similar to that of the normal third heart sound, but in the one case the sound is attributable to the stenosis of the mitral orifice and the thickening of the mitral cusps, whereas in the other the orifice and valves are normal but the rate of blood flow is increased. The former is the pathological, the latter the physiological, third heart sound.

Summary

In a consecutive series of 835 recruits, a duplicated second heart sound (generally associated with an apical systolic murmur) was present in 157 cases.

The duplicated second heart sound was best heard when the patient lay on his left side; the reason for this is discussed. Duplication of the second heart sound was much more common in men under 20 than in older recruits. Seventy per cent of the men in whom it was present were considered fit for Grade I. Radioscopy in these cases generally showed an increased prominence of the pulmonary arc.

Since the production of an obstructive murmur depends on the degree of obstruction *relative* to the velocity of the blood current, it is suggested that an increased rate of blood flow through a normal mitral orifice may be instrumental in producing: (*a*) the accentuation and roughening of the first heart sound heard in certain athletes, in thyrotoxicosis, and in other conditions in which the heart is overacting, and (*b*) the duplicated second heart sound heard in healthy subjects. Both these signs are therefore regarded as signifying a " relative " mitral stenosis.

This hypothesis entails a physiological conception of mitral stenosis based on the volume of blood which an orifice of a certain size can transmit in unit time.

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ELECTROCARDIOGRAPHIC PATTERNS OF COMBINED VENTRICULAR STRAIN

BY

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The characteristic electrocardiographic patterns of right and left ventricular strain have been recognized for some time. While originally deviation of the electrical axis, reflected in the direction of QRS in the limb leads, was taken to indicate ventricular hypertrophy (4, 5, 7, 9–12, 16, 23–35, 28, 29, 37, & 38), later studies showed that the S–T–T pattern (1, 8, 22, 26, 27, 30, 31, 33, & 41) presented the more reliable evidence of chronic ventricular strain and was indicative of ventricular hypertrophy even in the absence of deviation of the electrical axis (2, 19). Experience in recent years has shown that the use of multiple chest leads is imperative in distinguishing between records of left ventricular strain and those of myocardial infarction involving the anterior wall (3, 13, 14, 15, 17, 20, 32, & 40). It has been shown (6, 16, 21, & 24) that the patterns of chronic ventricular strain do not necessarily indicate unilateral ventricular hypertrophy, but more often indicate the site of preponderant hypertrophy, or what is equivalent, the site of greater ventricular strain. The occurrence of cardiograms presenting a combination of features characteristic of both right and left ventricular strain suggested to us that bilateral ventricular strain might be reflected on occasion in the cardiogram. We therefore undertook to analyse the various possible patterns suggestive of combined strain and to correlate them with the clinical and autopsy data.

The cases for this study were selected at random from the files of the Heart Station of the past few years. Records showing evidence of myocardial infarction, acute cor pulmonale, or digitalis effect were discarded, because these conditions are known to imitate right and left ventricular preponderance in the absence of demonstrable ventricular hypertrophy or to mask the true pattern when hypertrophy is present (18, 21). It has also been shown (18) that these conditions may imitate the changes indicative of combined ventricular strain. A total of 47 records (some previously reported) were found and form the basis of this study. They were readily subdivided into 6 patterns (see Table I and Figs. 1 to 4) as follows :

TABLE I

DESCRIPTION AND FREQUENCY OF THE VARIOUS PATTERNS OF COMBINED VENTRICULAR STRAIN IN 47 CASES

Type	Electrocardiographic Pattern	Number of Cases	Clinical or Autopsy Evidence of Combined Ventricular Strain	Figure
I.	QRS contour of right ventricular preponderance combined with the S–T–T contour of left ventricular preponderance.	6	6	Fig. I, B and C
II.	QRS contour of left ventricular preponderance combined with the S–T–T contour of right ventricular preponderance	1	1	Fig. 2 C
III.	Concordant pattern of left ventricular preponderance (QRS upright in the limb leads with S–T–T abnormalities)	11	8	Fig. 3 A
IV.	Concordant inverted pattern of heart strain (QRS inversion in all three limb leads without any Q waves present)	7	7	Fig. 3 B
V.	Prominent S waves in all the limb leads with the major QRS deflection upward in at least two leads (S-T–T abnormal)	3	3	Fig. 3 C
VI.	Small upright QRS_1 or equiphasic QRS_1 with an S_1, with deep S waves in leads II and III greater in size than the upward deflection of QRS_1 in lead I.	18	12	Fig. 4 A
	One record not fitting into any of the above described patterns	1	1	Fig. 4 B
	Total number	47	38	

* Aided by the A. D. Nast Fund for Cardiovascular Research and the Nelson Morris Fund.

Type I. The combination of a QRS contour of right ventricular preponderance (QRS_1 mainly inverted, with an S wave, and QRS_3 upright) and an S–T–T contour of left ventricular preponderance ($S–T_1$ depressed and bowed upward, with T_1 inverted or diphasic). (Fig. 1, B and C)

Type II. The combination of a QRS contour of left ventricular preponderance (QRS_2 and QRS_3 inverted, with S waves) and an S–T–T contour of right ventricular preponderance ($S–T_2$ and $S–T_3$ depressed, with T_2 and T_3 inverted). (Fig. 2 C)

Type III. Concordant type of left heart strain (30) (QRS mainly upright in all limb leads, with $S–T_1$ and $S–T_2$ depressed, and with T_1 inverted or diphasic). (Fig. 3 A)

Type IV. Concordant inverted type of heart strain (20) (QRS mainly inverted in all limb leads, but without Q waves). (Fig. 3 B)

Type V. Prominent S waves in all the limb leads, with either QRS_1 or QRS_3 mainly upright, associated with an abnormal S–T–T contour. (Fig. 3 C)

Type VI. Small upright or equiphasic QRS_1 (the latter with an S wave), with QRS_2 and QRS_3 mainly inverted, and with deep S waves larger than QRS_1. (Fig. 4 A)

One interesting case not fitting into any of the above categories will be described below. (Fig. 4 B)

In 81 per cent of the 47 cases selected, the cardiographic diagnosis of combined strain was substantiated by the clinical, radiological, and, when available, by the autopsy findings.

In most of the cases of the Type I pattern, serial records taken over a period of years were available, and the gradual evolution of this pattern could be followed (Fig. 1). All 6 were instances of old rheumatic mitral valvulitis; one showed in addition aortic valvular involvement, another showed

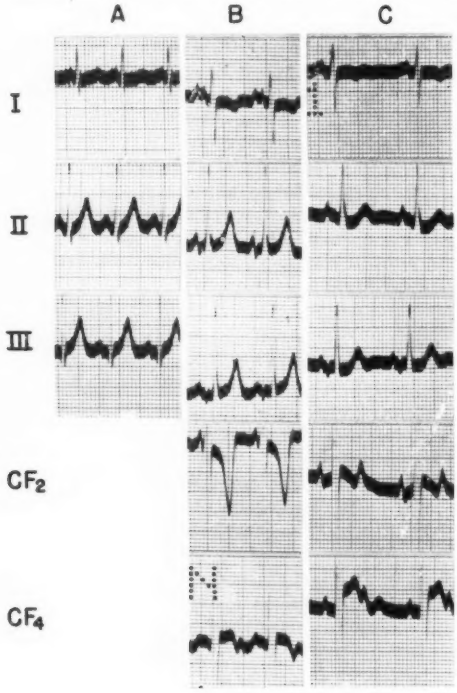

FIG. 1.

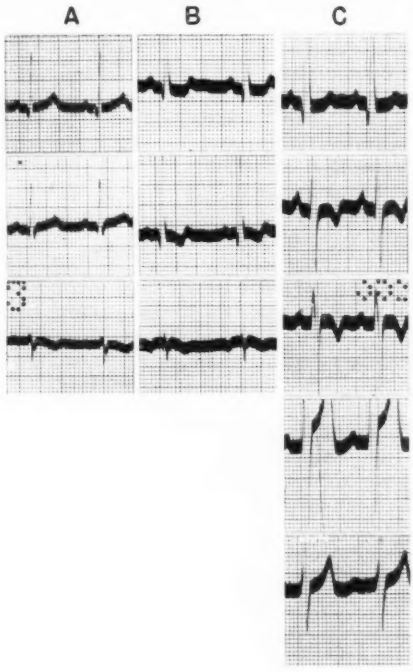

FIG. 2.

FIG. 1.—The development of the Type I pattern of combined ventricular strain in a patient with rheumatic mitral stenosis and insufficiency and aortic insufficiency. (A), taken at the age of 3, shows no axis deviation; (B) and (C), taken 3 and 4 years later, show a QRS pattern of right ventricular strain with an S–T–T pattern of left ventricular strain. Note the broad and notched " mitral " P waves.

FIG. 2.—The development of the Type II pattern of combined ventricular strain in a patient with rheumatic heart disease with mitral and aortic stenosis and insufficiency and a tricuspid lesion. (A), taken at the age of 14, shows a normal left axis shift. (B), taken 1 year later, shows an S–T–T contour in leads II and III which does not fit the contour of left ventricular preponderance of lead 1. (C), taken 7 years later, shows a QRS contour of left ventricular preponderance with T inversion in leads II and III, characteristic of right ventricular preponderance. Note the progressive widening of QRS between (A), (B), and (C).

deformity of the other three valves, and a third showed marked pulmonary emphysema. In two of the six cases autopsy findings corroborated the clinical diagnoses and the bilateral ventricular enlargement.

Only one example of the Type II pattern was encountered. This boy, aged 21, had clinical evidence of severe rheumatic carditis with mitral and aortic stenosis and insufficiency and a probable tricuspid lesion. Numerous records taken over thirteen years showed progressive inversion of QRS in leads II and III with inversion of T in those leads (Fig. 2). Digitalis was never given to this patient.

Kaplan and Katz (1941) in their description of the so-called concordant pattern of left heart strain suggested that the absence of axis deviation might be due to concomitant right ventricular strain, either on the basis of episodes of left ventricular failure (36) or an associated lesion putting a strain primarily on the right ventricle. They collected 17 cases and showed that 4 were attributable to combined mitral and aortic lesions, 9 to hypertensive heart disease with previous episodes of left ventricular failure, 2 to syphilitic aortic insufficiency with failure, and in the remaining 2 only hypertension was evident with no previous congestive heart failure. In one of the latter, the absence of axis shift was attributed to a displacement of the heart and mediastinum to the right by a massive pleural effusion.

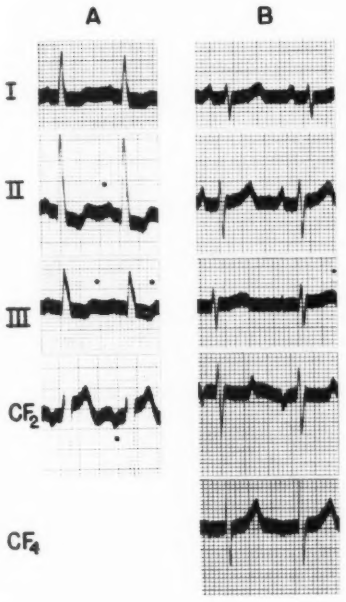

FIG. 3.

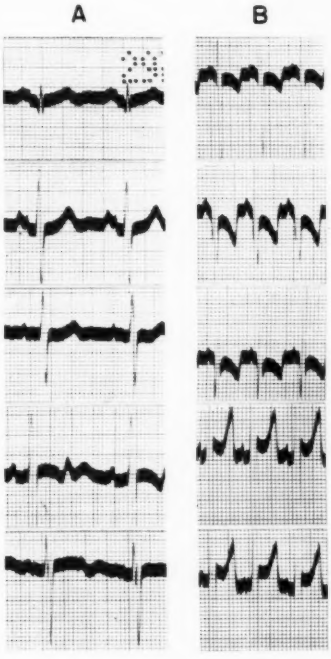

FIG. 4.

FIG. 3.—Three different patterns of combined ventricular strain. (A) shows the " concordant type of left ventricular preponderance " (Type III pattern of combined ventricular strain) in a 35 year old patient with hypertension and chronic emphysema. Heart weight at autopsy was 830 g., all chambers being dilated and hypertrophied. Note S–T depression and T inversion in all the limb leads as well as absence of axis deviation. (B) shows the " concordant inverted type of heart strain " (Type IV pattern of combined ventricular strain) in a 1 year old patient with mitral stenosis and insufficiency. QRS is of the S type in all leads. Note the large P waves in leads I and II. (C) shows prominent S waves in all three limb leads without inversion of QRS (Type V pattern of combined ventricular strain) in a 54 year old patient with stenosis and insufficiency of the mitral and aortic valves, hypertension, and emphysema and auricular fibrillation.

FIG. 4.—(A) shows the Type VI pattern of combined ventricular strain diagnosed on the basis of a small upright QRS in lead I and diphasic QRS complexes in leads II and III with deep S waves. The record was taken on a patient of 25 with mitral and aortic stenosis and insufficiency. Note the normal QRS contour in the chest leads and the typical " mitral " P wave pattern in limb and chest leads. (B) was taken on a three month old infant with Von Gierke's disease and marked cardiac enlargement, proven at autopsy. Combined ventricular strain was diagnosed because of the S–T depressions and T inversions in all limb leads. Note the large diphasic QRS complex in lead I.

In our 11 cases of this Type III pattern (Fig. 3 A), 8 were accounted for on the basis of combined heart strain; 3 of these were in cases of hypertension and chronic cor pulmonale due to asthma, bronchiectasis, and emphysema; 3 were due to combined mitral and aortic valvular lesions; 1 was due to hypertension combined with mitral stenosis; and the last was a case of severe hypertension with pulmonic valvular incompetence, either organic or functional. Of the 3 remaining cases, one had only hypertension, although X-ray showed enlargement both to the right and left, another had hypertension with only left-sided enlargement, and the third had only left ventricular hypertrophy with displacement of the heart and mediastinum to the right by massive pleural effusion from a pleural fibrosarcoma (reported with autopsy by Kaplan and Katz, 1941). Two of the cases, one with hypertension and emphysema and one with combined valvular disease, also came to autopsy, the hearts weighing 675, 725, and 830 g. respectively and showing bilateral ventricular hypertrophy.

None of the 7 cases with concordant inversion of the QRS in the limb leads showed true Q waves (Type IV). In the only case coming to autopsy, bilateral ventricular enlargement was present in association with an inter-atrial septal defect, the ætiology of the left ventricular enlargement not being evident. In all of the remaining 6 there was clinical evidence of bilateral strain. One of these appeared to be due to a combination of severe hypertension and chronic emphysema on an asthmatic basis, while a second (Fig. 3 B) had rheumatic mitral stenosis and insufficiency to account for the combined strain, although X-ray showed only slight cardiac enlargement. In the remaining 4 cases, congenital heart disease was present, 2 of these having an associated rheumatic mitral stenosis and regurgitation. The relative frequency of congenital heart disease in this type is striking, and one must consider the possibility that the abnormally directed QRS complexes may represent a congenitally abnormal pathway for the spread of the impulse rather than evidence of bilateral ventricular strain, although the latter is often present in congenital heart disease. This Type IV pattern is present in many of Schnitker's (1940) autopsy series of 106 cases of congenital cardiac disease.

There were 3 cases of the Type V pattern. These are similar to the preceding patterns in that S waves are present in all the limb leads, but differ in that the major deflection is not directed downward in all the limb leads. One of these came to autopsy and showed bilateral ventricular hypertrophy due to mitral and aortic lesions and in addition a patent foramen ovale. In the other two, X-ray showed cardiac enlargement both to the right and left. Both of these had mitral and aortic lesions with stenosis and regurgitation; one of them also had hypertension and emphysema (Fig. 3 C). The criteria for the differentiation of records such as these from those instances of normally occurring S waves in all the limb leads have already been discussed (39).

There were 18 instances of the Type VI pattern. Clinical or autopsy evidence of combined ventricular strain was present in two-thirds of these, autopsies of 7 being available. Of the 12 cases with combined strain, 3 had emphysema and hypertension, 3 had mitral stenosis and insufficiency, 2 had deformities of both mitral and aortic valves (Fig. 4 A), 1 showed severe coronary sclerosis and myocardial fibrosis with bilateral ventricular hypertrophy (heart weight 500 g. at autopsy), 1 showed bilateral hypertrophy (heart weight 475 g. at autopsy) with no demonstrable cause, and 2 showed bilateral hypertrophy with emphysema to explain that of the right ventricle, while the cause of the left ventricular hypertrophy was not disclosed. In the remaining 6 of this type none showed evidence, either clinically or anatomically, of combined ventricular hypertrophy, and only one showed any cardiac enlargement at all, this being in an autopsied case of emphysema with marked right ventricular enlargement. In two other cases, pulmonary emphysema was present with a resultant vertically placed heart which was not enlarged; another autopsied case showed brown atrophy of the myocardium with no other abnormalities; and in the last two cases of this group, one of which came to autopsy, there were no abnormal cardiac findings although the position of the heart was not recorded.

The frequency of pulmonary emphysema in cases showing this cardiographic pattern was striking, being present in 8 of the 18 cases (45 per cent). In these cases there was a vertically placed heart and a rotation of the heart on its longitudinal axis from right to left due to the low position of the diaphragm. It has been shown (18, 35) that this position change may be the sole abnormality in cases having this cardiographic contour, and this may be the mechanism in 3 of our cases with normal-sized hearts. Since emphysema also was present in 5 of the cases that had bilateral ventricular strain, it is possible that cardiac displacement played the major role in determining the abnormal QRS contours. However, the fact that this pattern occurred in 7 cases of bilateral enlargement without emphysema indicates that combined strain does give rise to this pattern *per se*.

The last record (Fig. 4 B) which did not fit any of the above patterns was taken from a three month old infant with Von Gierke's disease (confirmed by autopsy) in whom the heart was massively enlarged. The diagnosis of combined strain was based primarily on the depression of the S–T segments and deep inversion of the T waves in all the limb leads associated with a large equiphasic QRS_1 with deep S_1.

In order to estimate the frequency of the cardiographic patterns suggestive of combined ventricular

strain which occur in combined ventricular hypertrophy, a series of 149 consecutive autopsies in which cardiograms were available (Katz *et al*, 21) were reviewed. After eliminating cases with myocardial infarction, acute cor pulmonale on the basis of massive pulmonary embolism, and intra-ventricular block (QRS duration of 0·12 sec. or more) in the cardiogram, 29 cases remained in which the hearts were enlarged and both ventricles hypertrophied. The distribution of the patterns is shown in Table II. In over 25 per cent. of the cases with bilateral ventricular hypertrophy evidence

TABLE II

CARDIOGRAPHIC CONTOURS IN 29 AUTOPSIED CASES OF BILATERAL VENTRICULAR HYPERTROPHY

Cardiographic Pattern	No. of Cases	Percentage of Series
No axis shift or normal right or left axis shift	10	35
Left ventricular preponderance	8	27·5
Right ventricular preponderance	3	10
Combined ventricular strain	8*	27·5

* The eight records showing evidence of combined ventricular strain fell into the following types (see Table I): 2 into Type I, 2 into Type III, 1 into Type IV, 1 into Type V, and 2 into Type VI.

of this is visible in the cardiogram. It is thus apparent that the occurrence of these particular patterns should suggest the possibility of combined ventricular strain, when myocardial infarction, acute cor pulmonale, and digitalis effect have been ruled out, provided, of course, that the QRS duration is normal. Obviously, when there is clinical and radiological evidence of cardiac enlargement and the cardiogram shows no evidence of preponderance or only a normal right or left axis shift (as in 35 per cent of our autopsied series (Table II)), bilateral ventricular strain may still be present, the assumption being that the pattern of strain on one ventricle neutralizes that of the other almost completely. Furthermore, while these patterns are suggestive of combined ventricular strain, and in the cardiographic series analysed were substantiated clinically and by autopsy in 81 per cent of the cases, it does not follow that the pattern is directly due to the hypertrophy of both ventricles. In some instances the displacement of the heart and its rotation on its various axes may contribute to these so-called combined strain patterns. Furthermore, in some instances, it is not at all impossible that disseminated focal lesions may sufficiently alter the spread of the impulse to give rise to these patterns without accompanying prolongation of the total invasion time. This may also be brought about in congenital heart disease, by a congenitally abnormal placement of the conduction system. Until such a time as more definite evidence is available, the exact mechanism leading to these patterns must be considered *sub judice*. This, however, does not nullify the diagnostic significance of such records.

SUMMARY AND CONCLUSIONS

An analysis of 47 cases showing a combination of features of right and left ventricular strain in the cardiogram is presented. These were then correlated with clinical data and, in 19 instances, with the available autopsy findings.

Six electrocardiographic patterns of combined ventricular strain are described.

The cardiographic diagnosis of combined ventricular strain was substantiated by clinical, radiological, or post-mortem evidence in 81 per cent of the cases.

In a control group of 29 autopsied cases of bilateral ventricular hypertrophy in the absence of myocardial infarction, acute cor pulmonale, intra-ventricular block, or digitalis effect in the cardiogram, cardiographic evidence of combined strain was present in 27·5 per cent. In 35 per cent of the same series no ventricular preponderance and no axis deviation or only normal right or left axis shift were present; this substantiates the statement that absence of ventricular preponderance in the cardiogram in the presence of clinical or radiological evidence of cardiac enlargement is presumptive evidence of combined ventricular strain.

Other factors like displacement of the heart, congenital anomaly of the conduction system, or focal intraventricular block may be responsible for a pattern suggestive of combined ventricular strain.

Further anatomical correlation studies are necessary to establish the diagnostic accuracy of the cardiographic patterns of combined ventricular strain.

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PAROXYSMAL VENTRICULAR TACHYCARDIA

BY

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Paroxysmal ventricular tachycardia is comparatively rare. It was first differentiated from paroxysmal auricular tachycardia by MacKenzie (1908) through his study of simultaneous venous and arterial tracings. Others (Franck, 1894, and Hoffman, 1900) had hinted that this might be the case. The following year Lewis (1909) published the first electrocardiogram that supported this contention; the rhythm consisted of numerous isolated or continuous extrasystoles, eleven being the most occurring in one run.

Since Lewis's pioneer studies (1909, 1910), many workers have brought about a clearer conception of the condition and its prognostic significance. Their articles will be considered in more detail elsewhere in this paper.

DIAGNOSIS

Clinical evidence. Levine and Strong (1923) pointed out that it may be possible to make a diagnosis of ventricular tachycardia at the bedside. In auricular tachycardia the rhythm on auscultation appears to be absolutely regular. In ventricular tachycardia, however, there is sometimes an arrhythmia and sometimes a variation in the intensity of the first heart sound. Whether, however, it is possible to differentiate with any certainty this condition when showing arrhythmia from paroxysmal flutter with varying block or even from fibrillation at the rate of about 140, is extremely doubtful. Gallavardin (1920) and Prinzmetal and Kellog (1934) again drew attention to MacKenzie's observation that the presence of ventricular tachycardia can be shown by observation of the jugular pulse ; regularly recurring auricular waves at a slower rate than the pulse rate may be noted in some cases.

There is one further point that could be of some assistance in the diagnosis: the occurrence of a sudden marked rise and fall in the pulse rate in a patient with long-standing auricular fibrillation means that the episode is probably due to paroxysmal ventricular tachycardia, especially after heavy digitalization. Any of these points might suggest the diagnosis but the final and only proof is the electrocardiogram.

Electrocardiographic records. Robinson and Herrman (1921) were the first to lay down the diagnostic criteria—"The electrocardiogram must show that the cardiac impulses are arising in the ventricles and this is most clearly shown when a succession of auricular complexes can be made out occurring independently of and at a slower rate than the complexes of ventricular origin. The ventricular complexes are distinctly abnormal in form. This alone, however, cannot be taken as absolute proof as changes in form may be caused by changes in intraventricular conduction. When records made between attacks show there is no such disturbance then, the ventricular origin of the tachycardia is very probable, although disturbances of conduction may appear at a high cardiac rate which are not apparent when the heart is beating slowly. The presence of isolated ectopic beats before or after a paroxysm is evidence in favour of the tachycardia being ventricular, especially when the form of the complexes of the isolated beats is the same as the form of those of the paroxysm."

The presence of ectopic beats, however, before or after a paroxysm has no diagnostic significance, though Campbell and Elliott (1939) believe that where supraventricular extrasystoles are observed, the paroxysms are always of auricular origin. Amongst the cases to be described here, there are some with auricular premature beats occurring before and after the paroxysms of ventricular origin (Fig. 1). Isolated complexes identical with those of the paroxysm are almost impossible to find: the criteria should be changed so that the complex of an ectopic ventricular beat which is almost the same as those of a tachycardia may denote the ventricular origin of the paroxysm (Fig. 2 and 18).

* This work was done while holding a Research Fellowship in Medicine, Harvard University, 1938–39, and Walter Myers Travelling Studentship, Birmingham University, 1938–39. The basis of this paper formed part of a thesis submitted by one of us (W. T. C.) and accepted for the degree of M.D. of the University of Cambridge.

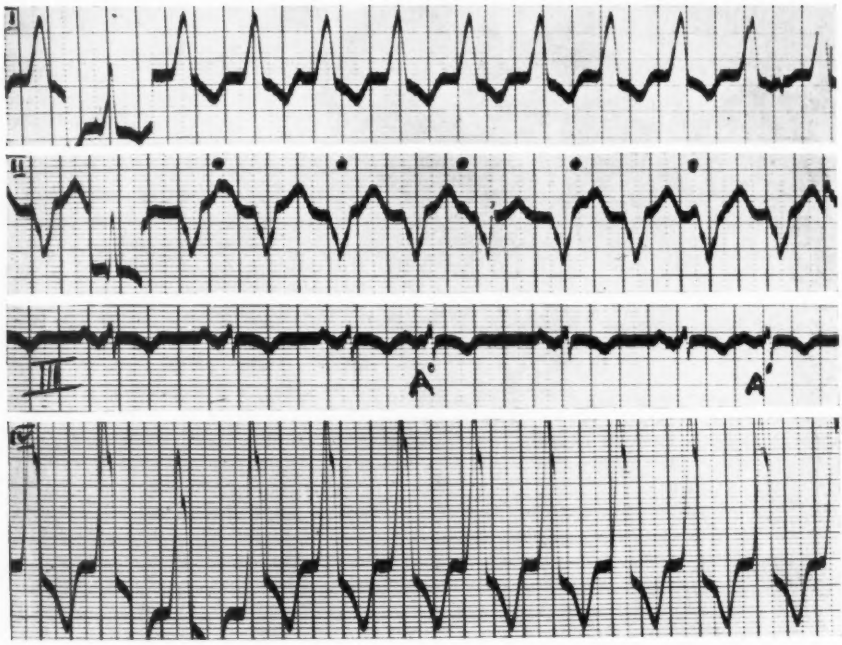


FIG. 1.—Case 22. Ventricular paroxysmal tachycardia, rate 140; auricular rate 75. Breaks in the ventricular rhythm in leads I and II are shown. The single beat in lead I simulates the Wolff-Parkinson-White type. Two premature auricular beats are shown during normal rhythm in lead III (marked A). The dots indicate the site of P waves.

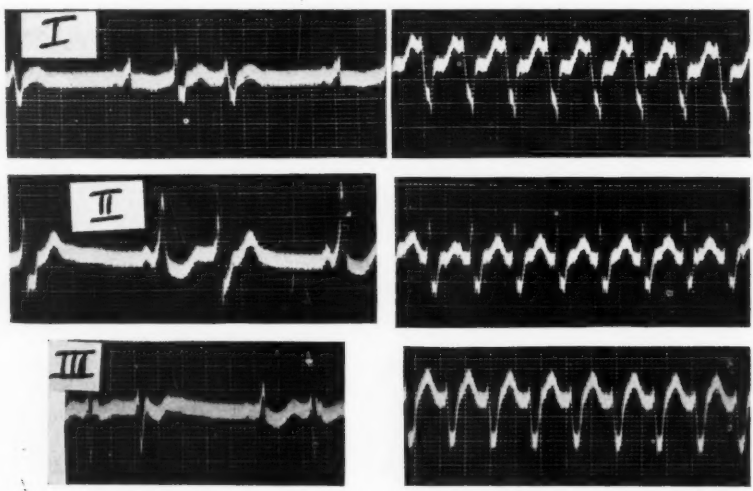


FIG. 2.—Case 27. Wolff-Parkinson-White type. On the left, S-A rhythm with numerous ventricular extrasystoles. On the right, paroxysmal ventricular tachycardia. No P waves can be identified but the ventricular complexes are sufficiently similar to the extrasystoles during normal rhythm to make the diagnosis.

Further, as has been suggested above, a succession of abnormal ventricular complexes occurring regularly and at a rate faster than the usual ventricular rate in the course of auricular fibrillation denotes ventricular tachycardia.

Lewis (1925) pointed out that it is difficult to be certain of the origin of paroxysmal tachycardia in any given example unless P waves or the beginning or end of the paroxysm are recorded. The actual mode of ending is not always a reliable index, as the compensatory pauses and the normal rhythm after both auricular and ventricular tachycardias is subject to great variation. However, on a few occasions the T wave of the last complex of a paroxysm is not the same as the remainder, thus providing evidence of superimposed and hidden P waves on the remaining T waves and so of its auricular origin. But in many examples of known auricular tachycardia this may be difficult to detect.

Strong and Levine (1923) carefully measured the time intervals between the QRS complexes and pointed out that there was much variation as opposed to the comparative regularity of auricular paroxysmal tachycardia. This has been used by some in differentiating the doubtful cases. We have, however, encountered cases of very regular rhythm in ventricular, and of considerable arrhythmia in auricular tachycardia. Too much stress has been laid on the irregularity.

Radiology. Kahlstorf (1936) states that with the kymograph it is possible to present indisputable evidence. He recorded one case of paroxysmal auricular tachycardia in which he was able to demonstrate the auricular rate of 280 satisfactorily by this method. He suggested that the method should be tried in ventricular tachycardia, and it might perhaps be useful where the diagnosis is doubtful.

Differential diagnosis. Some of the difficulties in diagnosis have already been mentioned. They can be well illustrated by Fig. 3, which was originally interpreted as showing ventricular tachycardia. It is, however, impossible to make out any auricular activity and the shape of the ventricular complexes may be due to aberration, so that one would not be justified in a definite diagnosis. The influence of the rate can well be shown in Fig. 4. The first record shows auricular flutter (A, 270; V, 135), while the second, taken in another attack with the same auricular rate, showed a 1 : 1 response of the ventricles but with aberration of the ventricular complexes.

Cases of the type described by Wolff, Parkinson, and White with a short P–R interval and wide QRS complexes cause some difficulty in diagnosis. They frequently maintain their abnormal complexes during a paroxysm or they may develop a greater degree of aberration or indeed actual ventricular tachycardia which is, however, rare (Fig. 2). Only a few other cases of ventricular tachycardia complicating this syndrome have been reported (Levine and Beeson, 1941). One of us (P. D. W.) believes that another case (Fig. 5) also shows paroxysmal ventricular tachycardia but it is not possible to identify any regular P waves or satisfy the other criteria laid down, so that paroxysmal auricular fibrillation cannot be ruled out as a possible diagnosis. Such rhythms in this type have caused difficulties in diagnosis on many occasions (Fig. 6).

These difficulties in diagnosis amply illustrate the necessity of applying strict criteria to the interpretation of the electrocardiograms in these cases.

Criteria for diagnosis. In the cases that are reported here, the following four electrocardiographic criteria have been applied.

1. The presence of P waves at a slower rate than that of the ventricles, during a paroxysm of tachycardia (Fig. 1).
2. A paroxysm of abnormal ventricular complexes, i.e. three or more at a rapid rate, occurring during auricular fibrillation (Fig. 7).
3. The onset of the tachycardia with an abnormal ventricular complex (Fig. 8).
4. Close resemblance of the complexes of ventricular premature beats to the complexes occurring during paroxysmal tachycardia (Fig. 2 and 18).

Any one of these conditions establishes the diagnosis of paroxysmal ventricular tachycardia.

Present Study

Number of cases. All cases of ventricular paroxysmal tachycardia occurring in the cardiographic records of the Massachusetts General Hospital during the 25 years from 1914 to 1939 have been collected. These were 24 cases among 51,000 records from about 25,000 patients. There were in addition, 3 patients whose tracings had been taken elsewhere. Three patients have previously been reported (Case 24, Jones & White, 1926; and Cases 1 & 9, Palmer & White, 1928). In addition to these 27 cases, there have been included in the appendix 5 further cases that had been diagnosed previously as ventricular but should be classed as doubtful or auricular in origin.

Ætiology. Of the 27 cases, 22 had coronary heart disease; 4 of these were still living when this study was completed in 1939, and 1 had not been traced. The remaining 5 had no other cardiac abnormality; 4 were alive and 1 had not been traced.

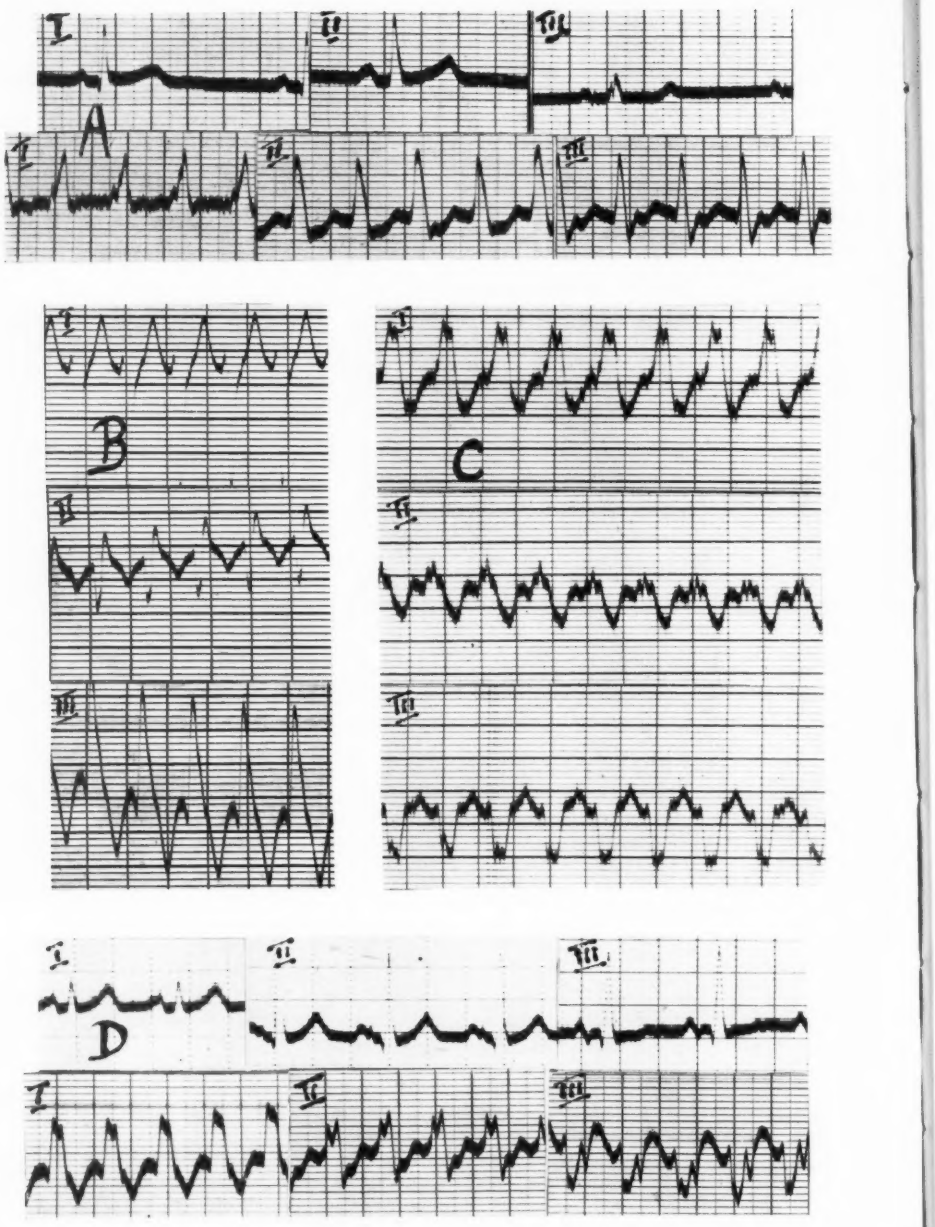
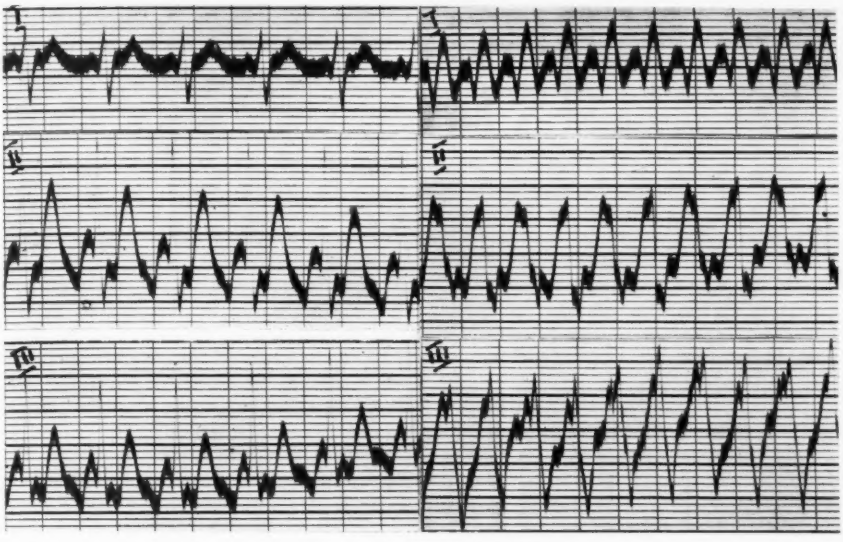


FIG. 3.—Short tracings from four patients (see appendix) in which there was insufficient evidence to make a diagnosis of paroxysmal ventricular tachycardia.

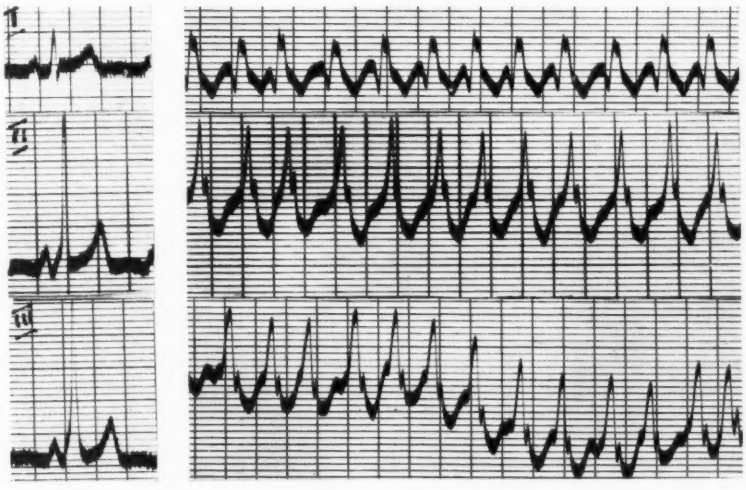
(A) and (B) are probably auricular in origin with aberrant conduction in the ventricles due to the rate while (C) and (D) are possibly ventricular. No definite P waves can be made out in any of the records.

(A) Case 28. (B) Case 29. (C) Case 30. (D) Case 32.



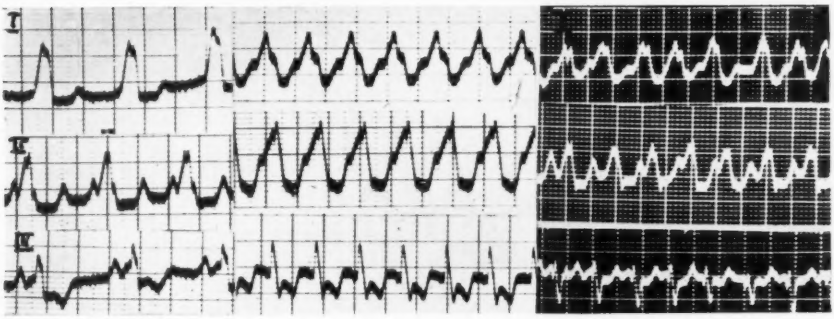
A B

FIG. 4.—Electrocardiograms, one of which simulates ventricular paroxysmal tachycardia. Both are from the same patient, and the auricular rate in each is 270, but 2 : 1 block is present in (A) and in (B) there is an aberrant ventricular response to every auricular beat.



A B

FIG. 5.—Case 31. On the left (A), normal rhythm with a short P–R interval and wide QRS complex (Wolff-Parkinson-White type). On the right (B), either paroxysmal ventricular tachycardia or paroxysmal auricular fibrillation. Possible P waves can be made out but no regular rhythm can be shown. The diagnosis must remain doubtful.



A B C

FIG. 6.—Wolff-Parkinson-White type. (A) Normal rhythm, (B) paroxysmal auricular tachycardia (or flutter), and (C) paroxysmal auricular fibrillation. All three records from the same patient, illustrating similarities in appearance to ventricular tachycardia.

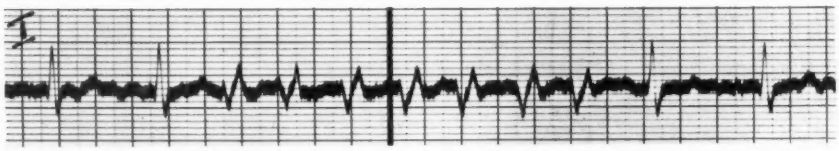


FIG. 7.—Case 17. Short paroxysm of ventricular tachycardia occurring during auricular fibrillation.

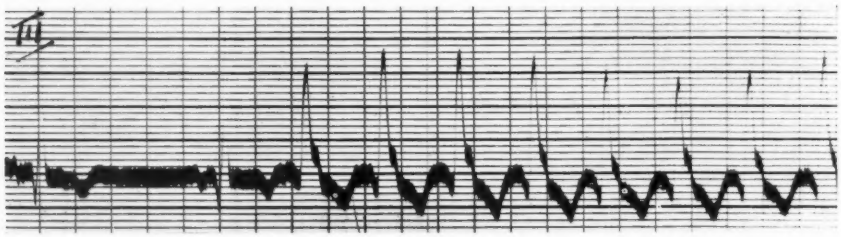


FIG. 8.—Case 24. Onset of a paroxysm shortly after the end of a T wave.

Sex incidence. 17 were males and 10 females. This ratio is somewhat higher for females than the figures that were given by Lundy and McLellan (1934) who found in their analysis of 94 reported cases that there were 68 males and 26 females: 14 of these 94 cases had no other cardiac abnormality.

Age incidence. The age incidence of our group is shown in Fig. 9. The table given by Strauss (1930) has been used for comparison (the lower part of the columns) and the figures of our group have been added (in the upper part of the columns). As would be expected, the greatest incidence accompanies the decade with the greatest incidence of coronary heart disease.

The youngest patients recorded have been aged 13 (Beeson & Levine, 1941), and 16 (McMillan & Bellet, 1932, and Lundy & McClellan, 1934). Our youngest patient (Case 24) was aged 18, but his father, a physician, had observed the attacks since the age of five.

THE ROLE PLAYED BY DIGITALIS

Traube (1851) pointed out that large doses of digitalis at first slow the heart and later increase the rate to one far exceeding that of the normal heart. This he supposed was due to the paralysis of the vagus.

Francois-Franck (1894), as a result of his experiments, described in remarkable detail the various disturbances of rhythm that took place. The digitalis arrhythmia was characterized by: repeated

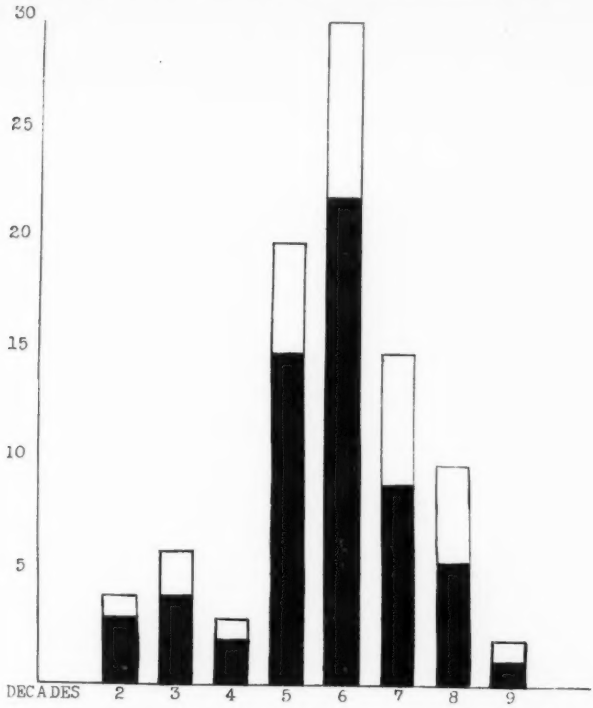


FIG. 9.—The age incidence of paroxysmal ventricular tachycardia. The figures for this series have been placed above those given by Strauss (1930), making a total of 90 cases in all.

close beats in groups of two, three, or more, producing the bigeminal or trigeminal pulse; numerous extrasystoles that are scarcely perceived at the wrist; groups of semi-tetanic contractions; intermittence of the heart for varying periods; and regular beats, with or without extrasystoles, between two periods of tachycardia. He completed his description—"Tous les désaccordes sont possible sous l'influence de la digitaline entre la fréquence et le rythme auriculaires et la fréquance et le rythme ventriculaires: les modifications des ventricules ne sauraient dône être subordonnées à celles de l'oreillette."

Cushny (1897), in his very extensive researches, noted exactly the same phenomena and believed that they were due to the increasing irritability of the cardiac muscle. All these findings were later confirmed by Robinson and Wilson with the aid of the electrocardiograph (1918).

Turning from experimental to clinical evidence, Vaughan (1918) suggested that the tachycardia observed in his two cases might be due to digitalis. Schwensen (1922) reported two cases and wrote that probably the administration of digitalis directly caused the attacks of ventricular tachycardia. He suggested that the sudden and unexpected deaths of patients under digitalis therapy was due to ventricular fibrillation resulting from overdosage.

Danielopolu in the same year (1922) published a report of three cases which he had observed in 1911 and 1913 and also ascribed them to digitalis or strophanthus. From the records published (pulse tracings) it is difficult to be sure of the exact nature of the tachycardia.

During the next few years there were numerous reports which illustrated the potentialities of digitalis in producing this rhythm (Fellerbaum, 1923; Reid, 1924; Marvin, 1928; etc.). Luten (1924, 1925) showed quite convincingly in a series of articles, the similarity between over-digitalization in animals, as demonstrated by Robinson and Wilson, and in patients. He regarded the alternation of the ventricular complexes which was being noted fairly frequently in such cases as the stage of intoxication just prior to fibrillation, and as an effect upon the conduction system rather than upon the muscle.

Gilchrist in 1926 recorded 5 cases of ventricular paroxysmal tachycardia and showed conclusively in one case that the abnormal rhythm appeared only upon the administration of digatalis and disappeared when the drug was withdrawn. Strauss (1930) found that of the 64 cases recorded

to that time, digitalis had been administered before the onset of the tachycardia in about 50 per cent, and of these there were some excessive doses while in others the dose was probably too small to have any effect. However, as Gilchrist had pointed out, and as Scherf and Kisch pointed out later, in very damaged and abnormal hearts even small doses of digitalis may be sufficient to cause abnormalities of rhythm.

An excellent commentary and summary of the effects of digitalis is given by Scherf and Kisch (1939), who reported the results of their observations, extending over fourteen years, upon 18 patients with ventricular paroxysmal tachycardia and alternating complexes. In 14, digitalis was probably the provoking and determining factor, but in 4 no digitalis was given; in these latter cases, they believed that there was gross myocardial damage. They thought that digitalis cannot produce the arrhythmia unless the heart is already damaged, because Kobacher and Scherf (1930) were unable to produce such arrhythmias in normal hearts of animals, and also because the reports of cases of suicide contain no mention of the production of any arrhythmia (e.g. Albeaux, Fernet, & Welti, 1939). In some of their cases the tachycardia frequently disappeared if the digitalis was discontinued but it returned if the drug was given again. On the other hand, tachycardia may not develop after the administration of excessive amounts of digitalis over a long period. They, therefore, assumed that the quantity of digitalis administered is not the factor of exclusive importance, but that the state of the heart muscle is chiefly responsible. They recorded one case in which the rhythm disappeared only during the administration of large doses of quinidine and of digitalis, in a young man aged 23 years.

There were 12 out of our 27 cases to which no digitalis had been given before the onset of the tachycardia. Of these, 5 were cases in which the only apparent abnormality was the arrhythmia, i.e. with presumably normal hearts. Of the 15 cases to which digitalis had been given, there were 5 in which the dosage had been greater than normal, and we are warranted in assuming that digitalis played a large part in the production of the paroxysm (Cases 2, 5, 6, 13, & 18; see appendix). There were 10 other cases to which digitalis had been given prior to the tachycardia (Cases 1, 3, 4, 8, 9, 10, 11, 16, 17, & 19).

Of the 7 cases of coronary heart disease that had had no digitalis before the onset of the tachycardia, there were 4 to which digitalis was administered in average doses after the onset (Cases 14, 20, 21, & 22).

There remain 5 cases of apparently normal hearts with ventricular paroxysmal tachycardia. These all had digitalis given to them at one time or another, in various dosage, without any noticeable effect, either in increasing the frequency or diminishing the number of the attacks.

To summarize, out of 22 cases of coronary heart disease showing ventricular paroxysmal tachycardia, 5 were probably related to digitalis administered, and 3 others may possibly have been so related; 1 in which no digitalis had been given before, may have been aggravated by digitalis; 7 had had digitalis but probably in doses that were unrelated to the tachycardia; 3 had had digitalis after the tachycardia without any aggravation of symptoms; and the remaining 3 had no digitalis at any time.

There had been no case in this series in which the ætiological role of digitalis was proved by therapeutic test, but it was probable in some of the cases. It is very likely, as Scherf and Kisch point out, that the quantity of digitalis is not the primary factor but rather the state of the heart muscle. One may go further and suggest that it is the state of the conducting tissues rather than of the contractile tissues that is of major importance.

Some cases of ventricular tachycardia could have been prevented. The method of rapid digitalization was popularized in 1920 and the danger involved has been generally realized only in recent years. The occasions for excessively rapid digitalization are not very common. Digitalis folia takes six hours before it begins to exert its maximum effect and yet it is extremely common to find the drug prescribed at three or four hourly intervals, thus allowing overdosage before the appearance of toxic symptoms. Six hourly intervals would be more rational.

Digitalis intoxication may arise, moreover, in a previously digitalized patient with the onset of diuresis and the liberation of large amounts of the digitalis that had been stored in the tissue fluids. It is quite possible to incriminate this mechanism in our cases. On looking through the reported cases and our own, the plea for more care in the use of digitalis seems wholly justified.

Rate and Rhythm of the Paroxysms

There is a great variation in the rate of the individual paroxysms. In this series the slowest is about 100, while the most rapid is 270. The average speed for 30 different paroxysms occurring in these 27 cases is 174. Campbell and Elliott (1939) found an average rate of 198 in their eight ventricular cases. There is no definite correlation to be found between the rate and the prognosis, although it is true that of the three patients with rates below 140, two died within a few hours while the third

was alive two years after the episode, and that the extremely fast rates of 250 and 270 were found in patients with otherwise normal hearts.

It is not uncommon for both auricular and ventricular paroxysmal tachycardia to show some irregularity in the timing of the complexes in the first two or three beats before taking on the regular rhythm of the paroxysm. Three cases of this group illustrate a gradual change in rate, either speeding up or slowing down of the rate of the paroxysm. Case 18 (Fig. 10) showed a gradual increase in rate,

FIG. 10.—Case 18. Onset of paroxysmal ventricular tachycardia with abnormal ventricular complexes. There is a gradual increase in rate from 150 to 190 beats per min. Lead IV (old technique).

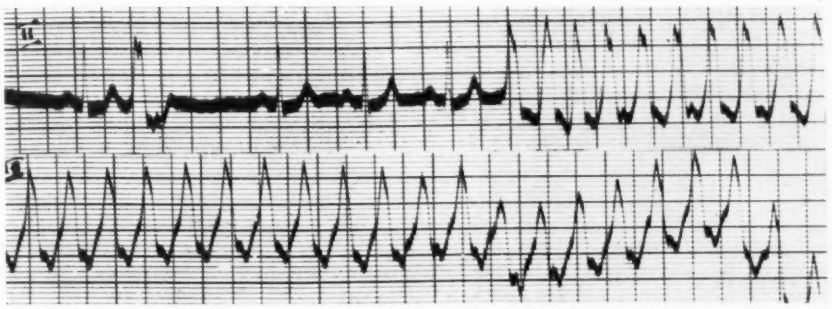


FIG. 11.—Case 26. Onset of paroxysmal ventricular tachycardia at a rate of 270 and gradual decrease to 220 beats a minute.

over about six beats from 150 until the rhythm appears to become regular at 190. Case 24 also showed a slight tendency to speed up. Case 26 (Fig. 11) showed the opposite phenomenon, starting at 270 and slowing down over the space of many seconds to the rate of 220.

Levine and Strong (1923) reported that while the intervals were regular in paroxysmal auricular tachycardia, they showed slight irregularity in ventricular tachycardia. They reported and gave illustrations of three cases. Probably, however, their Case 3 was not ventricular tachycardia but auricular flutter with aberrant ventricular response, the auricles beating at a rate of 280–300 and the ventricules responding with 4 : 3 block and some slight regular variation in A-V conduction. This would explain the great regularity in the irregularity of the intervals. The second case also may not be ventricular paroxysmal tachycardia for it is unusual to find both auricular and ventricular paroxysms in the same patient and the records that are given of the two conditions are not from the same lead. In the example of ventricular tachycardia given, the onset of the paroxysm is shown, but it is impossible to be certain that there is no P wave hidden in the preceding T wave or to identify any P waves in the ensuing paroxysm. Partly as a result of this article, there has arisen an exaggerated impression as to the irregularity of ventricular tachycardia. Irregularity of the nature or of the extreme degree shown in Levine and Strong's third case is extremely uncommon and should always lead to a search for some other mechanism.

Irregularity that can easily be seen on the tracings, is usually present in cases arising during auricular fibrillation (our Cases 8, 10, 17, & 20). It is present in an occasional case when the patient is very nearly dead (Case 12). Some irregularity is usually present in very short paroxysms, as in our own Case 23 where the measurements are shown on the electrocardiogram (Fig. 12). Among 15 of the tracings, however, in which there is a definite and prolonged paroxysm, 13 are perfectly regular, 10 as measured by calipers and time interval lines (Cases 3, 4, 5, 6, 14, 15, 19, 24, 25, & 27) and the other 3 (Cases 1, 11, & 22) as measured by the Lucas comparator. Case 13 appears to be irregular and the measurements of Case 2 show some slight irregularity. McKinnon (1934) also has found that the rhythm of the great majority of cases of paroxysmal ventricular tachycardia is perfectly regular.

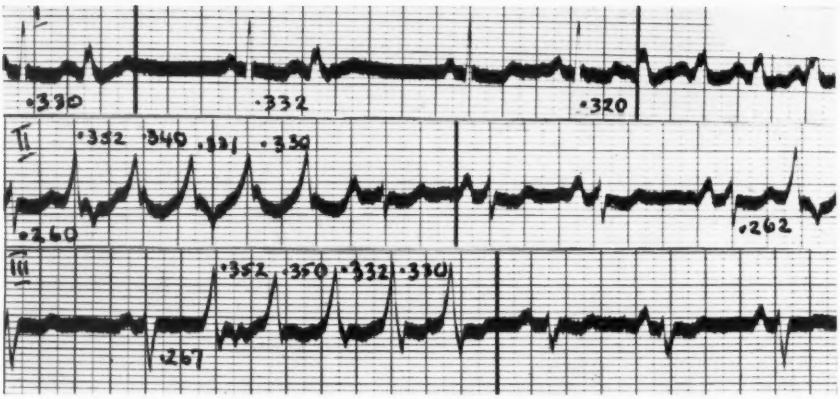


FIG. 12.—Case 23. Numerous short paroxysms of ventricular tachycardia. Comparator measurements show slight irregularity during the paroxysms. The onset of the paroxysms in lead II appear to take place at the same point in diastole on each occasion.

Campbell and Elliott (1939) also considered that any irregularity, which could be detected clinically, was more likely to indicate auricular flutter.

To sum up, the rhythm of ventricular tachycardia may be regular or slightly irregular, but there is no advantage in stressing the occurrence of irregularity, since marked irregularity is an exceptional finding.

DURATION OF THE PAROXYSMS

The duration of the attacks in 13 of our patients was short, being a few seconds in the majority and less than an hour in the remainder. There were a number in whom attacks lasted several hours. The longest paroxysm appears to have been in Case 3 whose attack probably lasted over 4 weeks. He was in the hospital for one month prior to his death, and all treatment was ineffective in stopping the paroxysm. The longest case on record seems to be that reported by Elliot and Fenn (1934) in a girl, aged 19; this lasted 32 days.

FACTS AND THEORIES AS TO THE PRODUCTION OF VENTRICULAR TACHYCARDIA

When there are numerous theories and each is supported by reliable workers, it is usually safe to say that none are satisfactory and that all contain some elements of the truth. In no subject is this more apparent than in the abnormal heart rhythms. Here elaborate theories have been built upon comparatively meagre knowledge of the human heart and a large amount of experimental work on the hearts of lower animals.

The most commonly accepted explanation has been that of a "circus" movement, based upon the experimental work of Mayer (1908). He caused a contraction wave to travel round a ring of tissue, cut from the bell of a jellyfish, by producing a temporary block in one portion. Garrey (1913, 1924), Mines (1913), Lewis, Feil, and Stroud (1918), De Boer (1920, 1927), and Wiggers (1940, 1941) are some of the workers who have put forward theories on the mechanism of the circus wave and modes of re-entry of the impulse to areas that were previously refractory.

Rothberger *et al.* (1913, 1922, 1931) held that all the "ectopic" rhythms could be explained by differences in the rate of impulse formation, due to an ectopic focus beating at a rapid rate. This idea was incorporated in the theory of parasystole (Kaufman & Rothberger, 1918), in which this focus was cut off from the remainder of the heart during normal rhythm by an area of block. The theory "tachisystole" was also put forward in various forms by Herring (1917), Haberlandt (1918), and Scherf (1928).

Geraudel (1925, 1926, 1928) also held that the differences between the "ectopic" rhythms were only those of speed of impulse formation. He put forward the theory of "cardionectors," based upon the specialized blood supply to the S-A and A-V nodes and the complete independence of these nodes from one another. Any abnormal rhythm was due to the speeding up of one or the other of these two centres.

The origin of ventricular tachycardia is closely bound up with that of extrasystoles. Lewis (1925)

pointed out that patients who present paroxysms of tachycardia constantly exhibit isolated extrasystoles during slow rhythm, which are usually of a similar nature to the complexes of the paroxysms and are provoked by similar agencies and terminated by similar means. For such reasons, he believed that paroxysmal tachycardia and extrasystoles were alike phylogenetically. He summed up much of the experimental work and present-day conception of extrasystoles. " In the frog all parts of the heart muscle are capable of originating rhythmic impulses. Many parts of the mammalian heart will initiate beats under particular circumstances, but there is little evidence that those containing no special tissue can keep the heart beating rhythmically in situ. There is little evidence to suggest that extrasystoles can spring from the ventricular muscle as opposed to the Purkinje system and there is some evidence to suggest the latter as their usual starting point."

Clinically, extrasystoles and paroxysmal tachycardia are very closely related, while in the auricle, the dividing line between paroxysmal tachycardia and flutter, and flutter and fibrillation, is difficult to define. On these grounds alone, there would be ample justification for regarding the basis for all these four rhythms as essentially the same. This view has been put forward by many workers (Kauffman & Rothberger, 1917; Garrey, 1924; Wiggers, 1937; and others).

However, no one as yet has laid the foundation upon which any theory for the tachycardia can be built, for few have suggested or shown any adequate reason for the S-A node during normal rhythm or the A-V node during heart block to continue to send out impulses. To postulate other centres, as in some of the theories, seems to introduce unnecessary complications. All the theories have been built up on circumstantial evidence and, although strong and undoubtedly correct in some instances, there has never been any direct proof for any of them. The experimental work upon which each theory has been built has always called forth a certain amount of justifiable criticism from other workers in the same field. Further, there has been no very convincing evidence put forward to show why the abnormal rhythm commences, why occasionally a single beat will cause a paroxysm of fibrillation and not tachycardia, why a paroxysm once started should ever cease abruptly, or why an extrasystole should not precipitate a paroxysm of tachycardia in every case.

The basic fact, upon which the theory of the ectopic origin of the ventricular premature beat has been founded, is the aberration of the ventricular complex. Very little attention has been paid to the aberrant ventricular complex on the occasions on which it is quite certain that the impulse has reached the ventricles through the A-V node. Lewis (1911) and White *et al.* (1916, 1928) have called attention to such cases and have shown conclusively that the earlier the auricular ectopic beat, the more possibility there is for the resulting ventricular response to show some degree of aberration. The sole reason for such an occurrence appears to be the degree of prematurity, and in any tracing that shows numerous ventricular extrasystoles, it will be seen that the earlier in diastole that the beat arises, the more aberrant become the ventricular complex.

In published tracings of induced extrasystoles (e.g. Lewis, 1925), the shape of the complexes also varies with the degree of prematurity. In the examples given, no complex is the same and none arises at the same time after stimulation. While these observations in no way disprove the original contention that the extrasystoles arise from various points in either ventricle, the experiments will also support the theory that the aberrant ventricular complexes are due to stimuli arising from a single centre at various times in the cardiac cycle, possibly in the case of the ventricle, the A-V node itself.

Direct stimulation of the human heart (Barker, Macleod, & Alexander, 1930; and Lundy, Treiger, & Davison, 1939) has not clarified the position, as it is possible to produce similar shaped complexes by stimulation of given points either in the right or left ventricles.

Consideration of the causes and precipitating factors of the cases of auricular tachycardia and fibrillation makes it clear that reflex action (possibly through temporary alterations in the physicochemical state of the conducting systems and the chemical mediators of the autonomic nervous system) rather than any organic disease plays by far the major role in their production. In the cases of ventricular tachycardia, coronary heart disease is present in 80 per cent of our cases. If, however, one takes into consideration the preponderant amount of coronary heart disease that comprises the material of the laboratory of the Massachusetts General Hospital, it seems evident that coronary heart disease *by itself* can only play a minor role. Infarction of the cardiac muscle with various local upsets in the coronary circulation should provide numerous occasions for the escape of the ectopic rhythm centres and initiation of various types of local block, etc. The fact remains that it does not do so in the vast majority of cases.

In recent years, evidence has been accumulating on the supernormal phase of the cardiac cycle and its possible role in the production of abnormal rhythms.

In 1912, Adrian and Lucas applied the term " supernormal phase " to a condition occurring in injured excitable tissue. They found that there was a short period, during recovery from a previous stimulus, in which the tissue became hypersensitive to new stimuli. They also showed that this supernormal excitability of nerve tissue was accompanied by a supernormal variation in conductivity.

Adrian in 1920 again confirmed this work and showed its presence in the frog's ventricle. De Boer (1920) noted that a single stimulus, applied to a desanguinated frog's ventricle some time after the refractory period was over, caused an extrasystole, whereas a stimulus applied immediately after the refractory phase caused a " continuous circulation," though he did not postulate a supernormal phase.

In 1924, Lewis and Master were the first to apply this conception to the human heart. In one of their cases, a case of paroxysmal heart block, the P waves were only conducted to the ventricle at a phase of the refractory period which is usually totally unresponsive. This phase lay between the summit and the end of the T wave. They likened this to the supernormal phase of Adrian and Lucas. In 1925, Ashman showed its presence in the conduction tissues of the turtle and, together with Hermann in 1926, suggested that a case of paroxysmal complete heart block could be explained by such a mechanism.

Since then a number of other cases have been described (Jervell, 1934; Luten D, & Pope, 1936; Scherf & Schott, 1939; and Kline, Conn, & Rosenbaum, 1939). Although doubt has been cast upon the interpretations of some of the tracings, it now seems to be accepted that the supernormal phase does occur at various points in the human cardiac cycle, and it may account for both A-V and V-A conduction in certain cases.

Eccles and Hoff (1934) have shown experimentally that a supernormal phase may occasionally be present in the pacemaker of the heart.

Erlanger and Gasser (1936) have shown the existence (in nerve) of certain after potentials, long after the period of excitation accompanying the propagation of the impulse, and that these potentials are associated with various phases of the recovery process. They also found that the supernormal phase which follows the relatively refractory period was associated with a negative after potential. This phase is very easily affected by many simple factors, such as asphyxia and alteration of the acid-base equilibrium. It might be noted here, in connection with the experimental production of ventricular fibrillation, that Schlapp (1932) showed that alkalosis, produced by overventilation, sensitized the ventricle to the action of adrenaline. Segers (1939), working with the frog's auricles, has also shown that the hyperexcitable phase is facilitated by adrenaline and sodium bicarbonate, and suppressed by ammonium chloride, potassium, and acetylcholine.

Gasser noted that nerves which show a marked supernormal phase were likely to respond to a single stimulus by prolonged repetitive discharge during which each succeeding discharge occurred at the height of the supernormal phase. He explained this phenomenon on an inherent residing subliminal stimulus which was thus able to give rise to spontaneous activity when the supernormal phase was present.

This reasoning has been applied to the Purkinje fibres of the heart by Goldenberg and Rothberger (1936), and it is suggested that the subliminal stimulus gives rise to an extrasystole whenever the supernormal phase occurs. By applying the idea of repetitive discharges, it is possible to suppose that an attack of paroxysmal tachycardia might occur.

Nahum and Hoff (1938, 1939) investigated the supernormal phase in higher animals, in cats, dogs, and a chimpanzee, and found that it occurred between the descending part of the T wave and the end of the U wave. They then investigated bigeminal rhythm in man and showed that in extrasystoles as a whole, the majority occurred on the descending limb of the T wave and in the area occupied by the U wave. Only a few occurred outside the supernormal area and these, they suggested, were of the nature of ventricular escape.

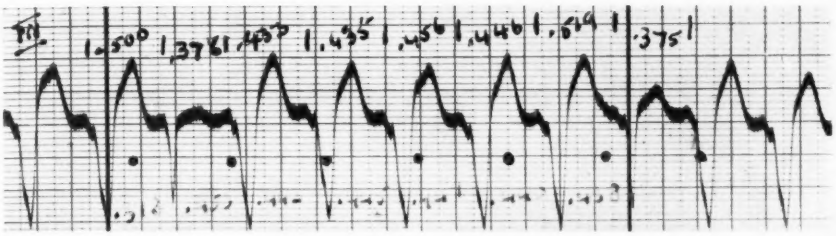
They point out that the ventricular conduction system possesses an inherent automaticity, usually subliminal. If, however, a marked supernormal phase develops, this latent stimulus may give rise to an extrasystole. Should the phase be continually present, bigeminy or even paroxysmal tachycardia might be produced. Even in the presence of a supernormal phase, should the internal stimulus be insufficient, no response may be expected: also should there be heightened automaticity of the conduction system, discharge would occur without the aid of the supernormal phase. Segers puts forward a similar view.

It is interesting to note that Lewis (1925) had postulated a " critical " period as an essential part of the mechanism to explain contrary effects produced by the vagus and sympathetic nerves and drugs such as chloroform, atropine, quinidine, and potassium salts.

We have been fortunate in securing a record of the onset of a paroxysm in 17 of our patients. The onset in 14 of these was at or near the end of the T wave (e.g. Fig. 8).

In Cases 21 and 23 (Fig. 13 and 12), there were a number of short paroxysms and in each the ventricular tachycardia, as measured by the Lucas comparator, started at the same point in diastole. The other three cases appeared to be initiated by an auricular complex. That these were paroxysms of ventricular tachycardia was shown by the presence of P waves at a slower rate during the paroxysm. In Case 13, the P–R interval was 0·32 sec. shortening to 0·18 sec. prior to the paroxysm, whilst in the other, Case 19, the P–R interval preceding the paroxysm was variable. In both, however, the occur-

rence of a P wave might be accounted coincidental, as the paroxysm commenced in the period of the cycle that may be associated with a supernormal phase. The auricular rate was also rapid in both. The third case showed a paroxysm beginning with a shortened P–R interval and a ventricular complex similar to the complexes seen in the Wolff-Parkinson-White syndrome (Fig. 14). It is only after this initial aberrant complex that the true paroxysm appears to begin.



IG. 13.—Case 21. Lead III taken during repeated paroxysms of ventricular tachycardia of varying duration; ventricular rate 140 and auricular rate 120. Comparator measurements made as to the time of onset in four successive paroxysms, were probably identical, 0·378, 0·376, 0·375 (the last two shown in the figure), and 0·373 sec.

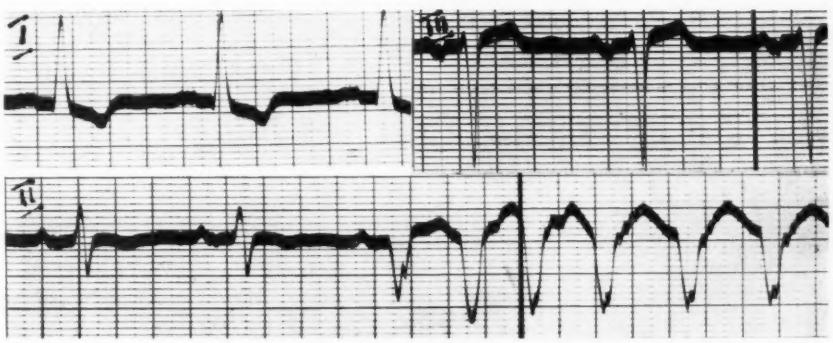


FIG. 14.—Case 10. Leads I and III (above) show normal rhythm with a P–R interval of 0·21–22 sec. Lead II (below) shows the onset of a paroxysm of ventricular tachycardia. The paroxysms is preceded by a P wave and a shortened P–R interval of 0·18 sec. The first ventricular complex appears to be different from the remainder of the paroxysm.

In Cases 22 and 24, the presence of a short P–R interval and slurred QRS complex was noted in the breaks in the tachycardia for one and two beats before reverting to the paroxysm again (Fig. 1). These findings suggest an abnormal excitability at the A-V node, and support rather than refute the hypothesis that a supernormal phase of the bundle and A-V node supplies the conditions for the onset of paroxysmal tachycardia.

To sum up then, there is evidence accumulating to suggest that extrasystoles can occur during the supernormal phase of a site of stimulus formation: when this happens, the complex is of abnormal type and in classical terminology would be designated as a right or left ventricular extrasystole. This phase is dependent upon factors that are essentially similar to those which determine the onset of paroxysms of tachycardia (changes in general metabolism, adrenaline, acetylcholine, potassium, etc.). This fact, together with the usual time of onset of the paroxysms, seems to offer some evidence in favour of the " supernormal phase " theory of paroxysmal tachycardias. There appears to be no necessity to postulate centres for the source of the ectopic rhythms other than the A-V node and the bundle, since aberration of the complexes are equally explicable on the basis of prematurity alone as by origin from ectopic focus.

At the moment, however, the conception of " re-entry " of the original stimulus through an area that was refractory at first, particularly as put forward by Wiggers (1940, 1941), is the most generally accepted explanation of extrasystoles, tachycardia, and the inception of circus movement.

Ventricular Paroxysmal Tachycardia with Alternating Complexes

There were four cases in this series showing alternation of the ventricular complexes (Fig. 15). Three of them (Cases 1, 9, & 24) have previously been reported. Three of the four had severe coronary disease, while the fourth (Case 24) had only very slight alternation and had a heart otherwise normal.

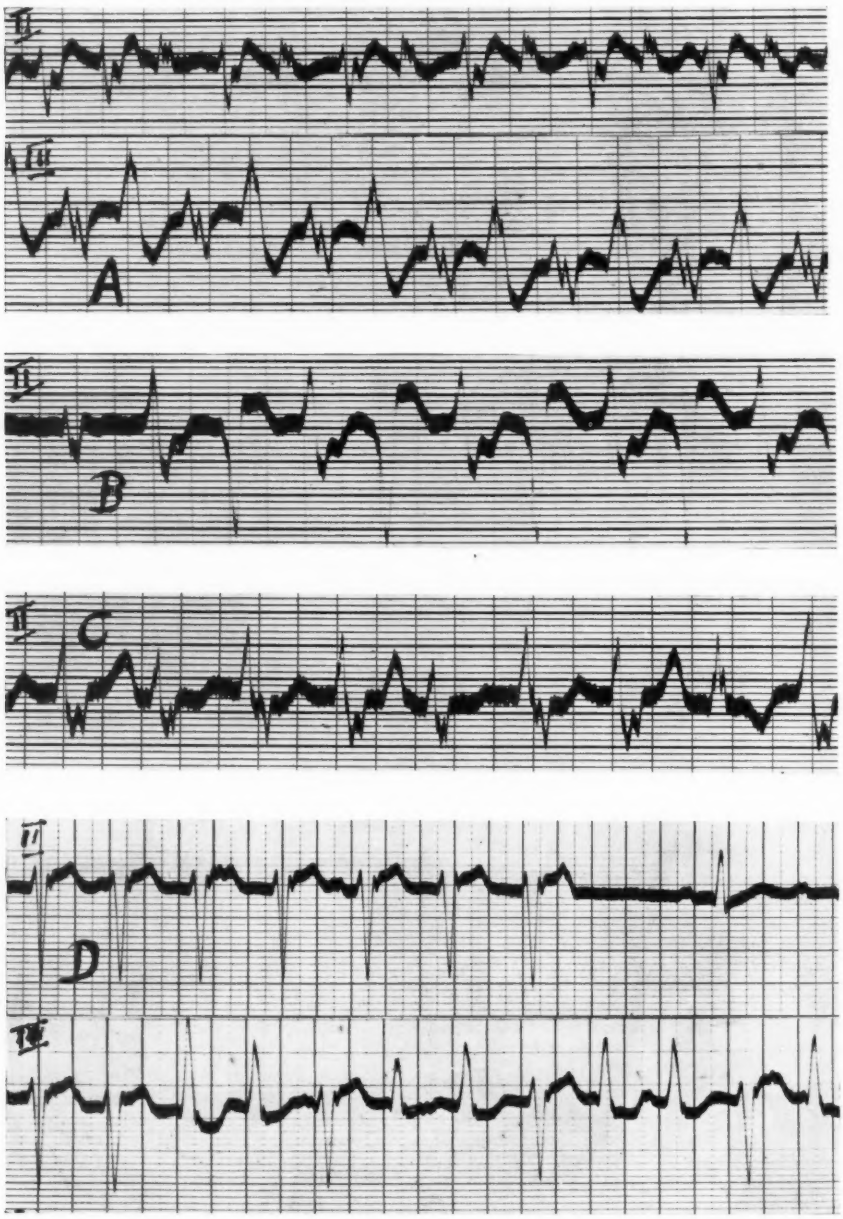


FIG. 15.—(A) At the top, leads II and III (Case 1), and (B) lead II (Case 9) show well-marked alternation. (C) Lead II (Case 24) shows very slight alternation. Electrocardiograms from these three cases have been published more fully elsewhere. (D) Leads II and IV (Case 2) shows the end of a paroxysm, and in the second strip, regular alternations of the ventricular complex. P waves are well shown.

The three cases with coronary heart disease died within a few days, while the fourth was still alive recently, twelve years after the electrocardiogram in question was taken. Digitalis had been given in excessive doses to two cases while it may or may not have played a part in the third case with coronary disease.

Various hypotheses have been put forward from time to time to explain the alternation. The tachycardia may arise from a single centre above the bifurcation of the bundle of His and the alternation may be the result of changing right and left branch block (Luten, 1924). The Purkinje fibres themselves may be refractory in alternate ventricles with successive beats so that alternate dextro- and lævo-cardiograms preponderate (Marvin, 1928). The alternation may arise as the result of the interplay of two separate rhythms (Marvin); and finally Palmer and White suggested the interplay of two separate circus movements in the ventricular muscle in alternate directions, but arising from the same site (figure of eight circus).

In several reported cases not only is there alternation in the complexes but also in the time intervals between the complexes. For example, Palmer and White carried out careful comparator measurements in two of the cases that are included in this group. The measurements they produced are striking in showing this alternation, and on this account they considered that alternation of the right and left branches was improbable owing to the difference in timing of the two types of complex.

It is possible, however, that such variations may be due to the inability to measure comparable points on the successive complexes. Neither the onset nor the peak of the R wave is identical in timing in two successive but different complexes. The beginning of the ventricular complex would be the ideal point to take comparator measurements from, and this is impossible to determine without the use of simultaneous leads. White, Leach, and Foote (1941) have shown conclusively that the beginning of the QRS complexes are frequently isoelectric in one of the leads. Marvin (1928) on the basis of irregularity of the timing of the complexes suggested that this indicated that the pacemaker must reside within the ventricles, and supposed that the resulting irregularity of the complexes was due to the varying time relations between the dextro- and lævo-cardiograms. The criticisms as to measurements may be applied to his tracings. It is probable that in all these cases, in spite of apparent variation in time intervals, the beats are regular.

Normal sino-auricular rhythm with alternating bundle branch block has been reported (Korns, 1922; and Scherf & Kisch, 1939). Since alternation of the ventricular complexes can take place in response to an impulse of supraventricular origin, and since the timing of the onset of the ventricular complexes has not yet been satisfactorily determined, Luten's explanation still seems the most rational. He wrote, " Digitalis intoxication results in a tachycardia which originates at or near the bifurcation of the main stem of the bundle. The action of the drug has also impaired to a considerable extent the conductivity of the bundle branches. An impulse is then transmitted over one (the right) branch but finds the other (the left) for the most part unable for the moment to transmit it. A small strand in the impaired left, however, does transmit the impulse but at a slower rate. This gives the picture of defective branch conduction. The next rhythmic impulse finds the bulk of the left branch restored and ready for conduction, but the bulk of the right branch has not yet recovered and so fails to transmit the impulse." Marvin (1928) had criticized such an idea on the basis of finding in one of his cases permanent bundle branch block, stating that in such a case, two centres would have to be present with one below the site of the branch block. Yater (1938), however, has shown that in such cases both bundles are severely damaged and that the electrocardiographic findings are merely an index of which branch is the most severely affected. Scherf and Kisch (1939) also believe that some, if not all, of their 18 cases can be explained by variations in conduction of impulses arising at a single point.

Therefore, on account of the reasonings we have already given, it is possible to suppose that the centre for ventricular paroxysmal tachycardia with alternating complexes lies in the bundle of His and in fact may be situated in the A-V node itself.

Prognosis

For the estimation of prognosis, the cases must be divided into two groups, those with organic heart disease and those with apparently normal hearts.

The occurrence of ventricular tachycardia in organic heart disease is a serious prognostic sign. Strauss (1930) found that of 50 cases with serious organic heart disease, 40 were dead within three hours to six months of the onset of the tachycardia, with an average duration of life of 24 days. The great majority of these received no specific medication.

The French workers, whose views have been well summarized by Froment (1932), hold that there are two types, a benign type of repeated ventricular extrasystoles occurring in young subjects (e.g. Cases 24 & 27); and the commonest type, a terminal or pre-fibrillation type which is the forerunner of death.

In our group of 21 cases of coronary heart disease, there were four still living at the time of writing. Two of them were extremely active, the time since the first paroxysm of tachycardia being two years in each case. Of the other two cases, one was a semi-invalid, four months after the occurrence of the paroxysm, and the other was crippled with vascular disease of the legs and had only just been discharged from the hospital four weeks after the tachycardia.

In our remaining 17 cases of coronary heart disease, death occurred within periods ranging from a few hours to eighteen months. Of these, there again seemed to be two groups, the one slightly larger comprising the patients dying within the first three weeks after the event, and the other in which they recovered for a while from that particular crisis and died some months later, in some cases suddenly and unexpectedly. While some of the first group would have died as a result of their coronary thrombosis, one or two might perhaps have survived a few months longer had treatment with quinidine or quinine been instituted. The exact length of survival can be seen in the appendix. The three cases with alternation of the ventricular complexes and coronary disease all died within two weeks. This is in accord with the experience of reported cases.

There are five cases of otherwise normal hearts in our group. Two of these were known to be living and well (Cases 23 & 25) at two and nine years respectively after the detection of the tachycardia. Case 26 had not been traced. Case 24 was alive in 1937, 12 years after the detection of the arrhythmia and 25 years after the probable onset; we were unable to get in touch with him more recently. Case 27 probably has an interventricular septal defect and also shows short P–R intervals and wide QRS complexes during normal rhythm; she was alive and well 14 years after the onset.

Case 15 might possibly throw doubt upon the diagnosis of the five irritable normal hearts. This patient, a woman aged 42 years, was diagnosed as having an irritable normal heart, but follow-up study revealed that she died three to four years later. The mode of death was not known but she has been classed as a case of probable coronary heart disease elsewhere in this paper. She was under observation for one year, during which treatment had little effect upon the frequency of the attacks. Occasionally similar cases have come to autopsy, e.g. Scherf's patient (McKinnon, 1934) who had paroxysms over five years, died with congestive failure, and had a heart in which there was no demonstrable disease. Campbell and Elliott (1939, p. 147) reported two similar cases. In these, both males aged 17 and 21 years, the paroxysms had been present over periods of five years and six months respectively before sudden death occurred.

The prognosis then is generally poor though exceptions are met with. A few cases with organic disease will manage to survive and young patients with apparently normal hearts have a good chance of lengthy survival.

Treatment of Paroxysm

Quinidine appeared to help the two patients with coronary heart disease who lived longest and at last account were still actively working. In two cases it seemed to counteract the effect of digitalis very rapidly, although not averting the fatal issue in either case. No effect could be obtained in Case 3 who was given a minimum dose of 18 grains daily and a dosage pushed to toxic levels on three occasions during the month he was in hospital.

Earlier writers (Levy, 1922; Drury *et al.*, 1922; and Levine, 1927, etc.) stressed the possibility of producing ventricular fibrillation with quinidine. Cases, too, have been reported in which the ventricular tachycardia only ceased on its withdrawal. Such cases, however, are rare and some of the examples reported have been attributed to quinidine wrongly. Occasionally perhaps the heart is in such an irritable state that any cardiac drug will provide the necessary stimulus for the tachycardia. We believe then, that the possibilities of inducing ventricular fibrillation should never weigh against the use of quinidine.

In our group of cases quinidine in various dosage has been given only by mouth. For example, Case 19 received 3 grains at half-hourly intervals for five doses before the rhythm became normal after an attack which lasted six hours. Quinidine may be given in 3 to 6 grain doses every two to three hours until either restoration of normal rhythm occurs or signs of intolerance develop. The necessary dose shows a great variation from patient to patient. When the rhythm does become normal, a daily maintenance dose should be continued for three to four months at least. There appears to be no contra-indication to the prolonged administration of quinidine. Case 21 and Case 23 both took 3 to 6 grains of quinidine daily for over two years and have shown no ill effects from the drug; other patients have taken even larger doses of the drug for many years without harm.

Treatment with intravenous injections of quinidine has been reported on favourably by Hepburn and Rykert (1937). They treated 9 cases with intravenous quinidine, 50–60 grains dissolved in 500 c.c. of 5 per cent glucose and given at a rate of 100–120 c.c. an hour. They pointed out that of these nine cases six were alive at the time of writing, for period up to four years since the tachycardia.

whereas only one out of nineteen cases who were not so treated lived longer than 15 days. Others (Bunn, 1932 and Battro, 1937) have also had good results.

The most convenient and effective method of stopping ventricular tachycardia that has proved refractory to drugs by mouth is, however, the use of quinine dihydrochloride by intramuscular injection, 5 c.c. of aqueous solution containing 7½ grains (0·5 gram) given every two hours until normal rhythm is restored or severe cinchonism results (Riseman & Linenthal, 1941).

Mecholyl (acetyl-B-methylcholine chloride) has been used with good results in paroxysmal auricular tachycardia, and in such cases, ventricular standstill is not uncommon. Mecholyl has also been used experimentally by Nahum and Hoff (1934) to prevent the onset of ventricular tachycardia induced by the action of benzol, adrenaline, and electrical shocks. It is not surprising, therefore, that it has been used for the treatment of ventricular paroxysmal tachycardia; Stern (1937) reported failure in two cases so treated.

It has been suggested (Hall, 1939), however, that acetycholine causes coronary artery spasm and certainly in some patients, its administration causes symptoms well-nigh indistinguishable from those of angina pectoris. There is clearly an element of danger in using such a drug in hearts of the sort usually found in patients with ventricular paroxysmal tachycardia. We believe, therefore, that if this drug must be used, it should be given only to young patients (e.g. Cases 24, 25, & 27) who have otherwise normal hearts.

There will remain a few patients in whom the attacks of ventricular tachycardia can be controlled only by the administration of full doses of both digitalis and quinidine (e.g. Scherf and Kisch's case).

Summary

We have reported 27 cases of ventricular paroxysmal tachycardia: 24 of these were found in a review of some 51,000 plates and films taken on about 25,000 patients in the Cardiographic Laboratory of the Massachusetts General Hospital over a period of 25 years from 1914 to 1939.

The criteria for diagnosis were the electrocardiographic findings. Fulfilment of any one of the following four points justifies the diagnosis.

1. The presence of P waves at a slower rate than that of abnormal QRS waves during a paroxysm of tachycardia.
2. A paroxysm of abnormal ventricular complexes, that is, three or more, occurring during auricular fibrillation.
3. The onset of the tachycardia with an abnormal ventricular complex.
4. Close resemblance of the complexes of ventricular premature beats to the complexes occurring during paroxysmal tachycardia.

Coronary heart disease was present in 22 of our 27 cases, 4 had apparently normal hearts, and 1 was thought to have a congenital ventricular septal defect. There were 17 males and 10 females, the youngest being aged 18 years and the oldest 81 years.

Digitalis had been administered to 13 of the 27 cases before the onset of the tachycardia. It was probably the chief ætiological factor in at least 5 of these cases.

It is suggested that abnormalities of the ventricular complexes of premature beats are responses to stimuli arising in the A-V node or bundle or main branches at a point in the cardiac cycle when the conducting tissues are still partially refractory. The onset of ventricular tachycardia was generally in the part of the cycle that has been associated with the supernormal phase. The mechanism of ventricular tachycardia with alternating complexes may be due to abnormalities in conduction along the bundle branches in response to impulses arising in the A-V node.

The prognosis is generally, but not always, poor. Only two patients with coronary heart disease survived longer than two years after the first attack. Five patients with hearts otherwise normal have survived to date, periods varying from two to fifteen years.

Quinidine or quinine should be used in adequate dosage in the treatment of the attack, being given either by mouth, intramuscularly, or intravenously. Quinidine sulphate is most conveniently given by mouth in the dosage of 6 to 9 grains every 2 hours for 5 to 6 doses under close observation and preferably with electrocardiographic control. If quinidine fails, quinine dihydrochloride, grains 7½ subcutaneously, every 2 hours, is recommended to stop the paroxysm and even to save life. A daily maintenance dose of quinidine by mouth (3 grains of the sulphate, 4 times a day) may be continued for prophylactic purposes for an indefinite time.

Appendix of Case Notes

In all these cases, the age given has been the age at death or, in the cases of those living, the age at the completion of the survey. EC. is used for electrocardiogram.

Case 1 (Fig. 15 B). A man, aged 50 years, had angina pectoris for three years and an attack of coronary thrombosis ten days before admission to hospital. There was slight congestive failure and a pulse rate of 190 with a B.P. of 140/105. On admission, he was given large amounts of digitalis, 27 grains in all, but died 40 hours after entry. Autopsy showed a heart weighing 545 g. with signs of fresh infarction at the apex of the left ventricle; a recent thrombus was present in the descending branch of the left coronary artery.

Case 2 (Fig. 15 D). A man, aged 80, was admitted in marked congestive failure. B.P., 160/90. Fairly rapid digitalization was carried out, 24 grains in 84 hours in this man who weighed but 115 pounds. The presence of ventricular tachycardia with alternating complexes at the end of this period was noted. EC., slight prolongation of the P–R interval and slight sagging of the S–T segments in leads II and III gave some indication of the digitalis effect. Death occurred 48 hours later. At autopsy the heart weighed 575 g. and showed diffuse coronary sclerosis.

Case 3 (Fig. 16). A man, aged 48, was treated for hypertension and coronary heart disease, following an attack of coronary thrombosis three years previously. After a cold, he developed congestive heart failure and ventricular tachycardia. Digitalis, 20 to 30 minims, t.i.d., had been administered

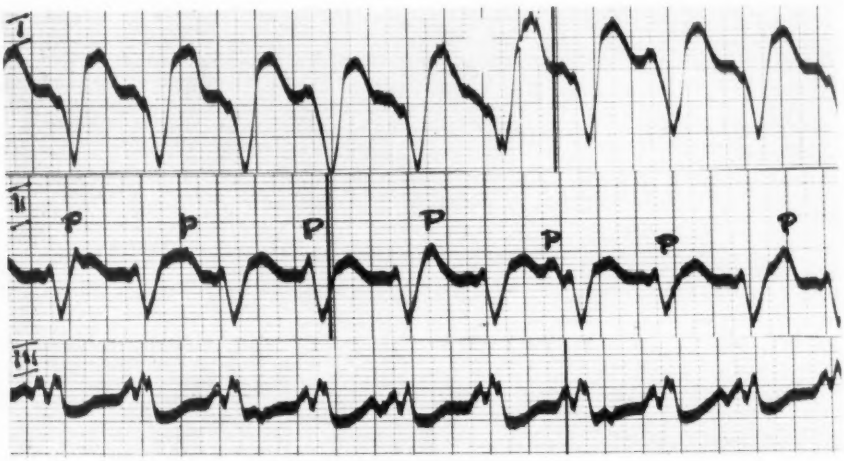


FIG. 16.—Case 3. Ventricular tachycardia at a rate of 140; auricular rate, 95. This attack lasted for more than twenty-eight days, probably for six weeks, terminating in the patient's death.

for one month prior to admission. No treatment, even quinidine in toxic doses, availed to stop the rhythm. He died one month after admission when digitalization was again being attempted. Ventricular tachycardia had been present for about six weeks. Autopsy showed a heart weighing 700 g. Most of the anterior wall of the left ventricle and lower part of the interventricular septum had been replaced by fibrous tissue.

Case 4. A man, aged 70, who had stopped work a few weeks previously owing to shortness of breath, was admitted to hospital with Cheyne-Stokes breathing and marked congestive failure. EC., ventricular tachycardia. He died 12 hours after admission. Digitalis, 6 grains, was given in hospital but the dosage given over the previous three weeks was not known. Autopsy showed a heart weighing 700 g. with diffuse coronary atherosclerosis.

Case 5. A man, aged 60, had had large doses of digitalis, 4·5 grains daily, for one week which should have been enough to complete digitalization, but he continued with 3 grains daily for a further week at the end of which time he had diarrhœa and attacks of ventricular tachycardia. A further 6 grains were given in hospital. He died suddenly and unexpectedly 20 hours after admission, quite possibly the result of ventricular fibrillation. His heart weighed 680 g. and showed moderate left ventricular hypertrophy and diffuse coronary atherosclerosis. EC., very little evidence of digitalis intoxication.

Case 6. A man, aged 55, was, compared with some of the other cases, in very mild heart failure. Massive doses of digitalis, however, had been given on admission, 54 gains in 120 hours, at the end of which time he showed ventricular tachycardia. Digitalis had been continued in spite of the continuance of this arrhythmia until his death seven days later. Shortly before death an attempt was made to control the attacks with quinidine. The effect of the digitalis on the EC. was to produce periods of bradycardia during which there was complete A-V dissociation, the S–T segments showing very little deviation.

Case 7. A man, aged 53, was admitted for fainting attacks following an attack of abdominal pain two months previously. A diagnosis of coronary thrombosis and attacks of ventricular tachycardia was made. He died 18 months later while taking an automobile test. No autopsy.

Case 8. A man, aged 57, had suffered with symptoms of hypertensive heart disease for over a year. He was admitted to the hospital after the onset of auricular fibrillation and an exacerbation of his symptoms: B.P., 220/120. He was kept on a maintenance dose of digitalis with rest periods and died fourteen months later in congestive failure. No autopsy.

Case 9 (Fig. 15 B). A man, aged 45, had been admitted to the hospital seven years previously with congestive failure, and recently with auricular fibrillation and congestive failure of two weeks' duration; he had been in fairly good health since his first admission; B.P., 130/100. He was given 30 grains of digitalis over the first 48 hours when the EC. revealed ventricular tachycardia with alternating complexes. He developed pneumonia and died 7 days later. No autopsy.

Case 10 (Fig. 14). A man, aged 66, was treated for hypertension and coronary heart disease with a daily maintenance of digitalis for four years prior to his death, being admitted to hospital on three occasions for congestive failure. EC. showed ventricular tachycardia during his last admission to hospital, 8 months prior to his death. No autopsy.

Case 11. A man, aged 49, was admitted complaining of abdominal pain for which an exploratory laparotomy was performed. He then developed congestive heart failure and cardiographic changes of coronary thrombosis. Following digitalization, 42 grains in 14 days, he had an attack of ventricular paroxysmal tachydardia of 6 to 8 hours' duration. Digitalis was continued with normal maintenance dose. He died 8 months later. No autopsy.

Case 12. A woman, aged 44, developed a pelvic abscess, following an operation for hyperthyroidism and a diagnostic dilatation and uterine curettage. During convalescence she had a cerebral embolism, and an EC. during this upset showed the presence of ventricular tachycardia. She died a few hours later. No autopsy.

Case 13. A man, aged 60, was first seen by us in a state of digitalis intoxication, having for the past three-and-a-half months taken 1·5 grains three or four times daily. When seen he had been semi-conscious and delirious for nearly four days while his pulse, normally 70, showed numerous runs of tachycardia at the rate of 150. The ventricular tachycardia showed no signs of stopping after omitting the drug for two days but stopped immediately with quinidine. The EC. then showed prolonged A-V conduction, 0·32 sec. (six months previously, 0·24 sec.). He was thought to be well on the way to recovery when he developed signs of lung involvement. He died six days after the cessation of digitalis.

Case 14 (Fig. 17). A woman, aged 62, had stopped working twelve months previously owing to shortness of breath. One week prior to entry, she had had an attack of fainting and had been weak

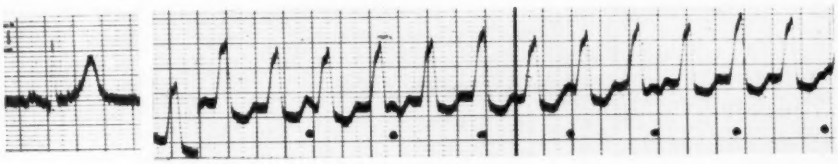


FIG. 17.—Case 14. Ventricular paroxysmal tachycardia rate 160. P waves are shown at a rate of 100, and are shown with dots.

ever since. On admission she had congestive failure and a rapid pulse rate which was shown by EC. to be ventricular tachycardia. Digitalis given after onset, 36 grains in 4 days, and thereafter maintenance dose of 1·5 grains. Follow-up study two years later revealed that she had died but the date and details were unknown.

Case 15. A woman, aged 42, was admitted to the hospital on account of a neck swelling and a feeling of compression there, of one year's duration, and palpitation of six months' duration. There was a goitre but no signs of hyperthyroidism were detected; EC. showed ventricular paroxysmal tachycardia. Hemi-thyroidectomy was performed for pressure symptoms. She died more than eighteen months later; the details were unknown.

Case 16. A woman, aged 52, had symptoms of hypertension and coronary heart disease for one year. B.P., 210/100: taking small and varying quantities of digitalis for the previous five months. EC. whilst in hospital showed attacks of ventricular tachycardia. She made very little improvement and died at home three months later. No autopsy.

Case 17 (Fig. 7). A man, aged 54, had suffered with auricular fibrillation for seven years, for which he had been taking small quantities of digitalis. His symptoms had been more marked over the previous five months; EC. showed short runs of ventricular tachycardia. His subsequent fate is unknown.

Case 18 (Fig. 10). A woman, aged 59, had been taking 2 to 3 grains of digitalis daily for a year and then three weeks previously had increased her dosage to 6 grains daily. She was admitted in marked congestive failure, complaining of much blurring of vision, weakness, and marked loss of appetite. B.P., 160/110. EC. showed ventricular tachycardia and markedly depressed S–T segments in leads II and III. She improved somewhat with diuretics, on the omission of digitalis. She died at home about four weeks later.

Case 19. A man, aged 63, had suffered with angina pectoris for 18 years and was admitted owing to an increase of symptoms and tachycardia for the previous three weeks. Following 1·1 grain of digitalis over 36 hours, he developed ventricular tachycardia which eventually was controlled by large doses of quinidine, a maintenance dose of which for the next three months completely controlled the arrhythmia. On re-admission, 18 months later, another paroxysm of ventricular tachycardia of twenty hours' duration was again controlled by quinidine. Digitalis probably played no part in this case.

Case 20. A woman, aged 72, had been treated for arthritis for many years. Four years previously she had been admitted to the hospital with coronary thrombosis. Following an increase in her cardiac symptoms, she was readmitted. EC., auricular fibrillation with short runs of ventricular tachycardia. The tachycardia was noted again following digitalization. She was still alive four months later, taking a daily maintenance dose of digitalis.

Case 21 (Fig. 13). A man, aged 72, had suffered with a duodenal ulcer for over 30 years. Two years previously he suffered a coronary thrombosis and during convalescence he developed ventricular tachycardia. Digitalization made the tachycardia more troublesome. On omitting it and giving a daily dose of quinidine, no further trouble was experienced. He was still alive two years after his heart attack.

Case 22 (Fig. 1). A man, aged 71, had been known to have had coronary heart disease and intermittent claudication of the legs for the previous four years. He was admitted with an occlusion of an artery of his leg, and showed slight congestive heart failure and an EC. revealed ventricular tachycardia. Digitalization was carried out without any ill effects, 33 grains in four days followed by maintenance dose of 1½ grains. He was discharged home much improved.

Case 23 (Fig. 12). A woman, aged 46, had undergone X-ray treatment for hyperthyroidism apparently with benefit twenty years previously. Three years ago she again attended the hospital on account of dizziness and giddiness. The heart was thought to be slightly enlarged and an EC. showed the presence of attacks of ventricular tachycardia. Paroxysmal tachycardia was thought to be the cause of her faint spells. She has, therefore, taken a maintenance daily dose of 3 to 6 grains of quinidine with great improvement in her symptoms and lessening of the attacks of tachycardia. She is now well.

Case 24 (Fig. 8 & 15 C). A man, aged 30, was first seen by us at the age of 18 years owing to repeated attacks of tachycardia which had been present since childhood. His father, a physician, had observed them at the age of 5. His only symptom had been a consciousness of almost continuous spells of rapid heart action. Examination did not reveal any obvious abnormality while an EC. showed numerous short runs of ventricular tachycardia. Treatment did not appear to improve his condition.

Case 25 (Fig. 18). A woman, aged 42, began to have attacks of paroxysmal tachycardia eight years ago. They have been and are still frequent and fairly persistent. On examination she has always

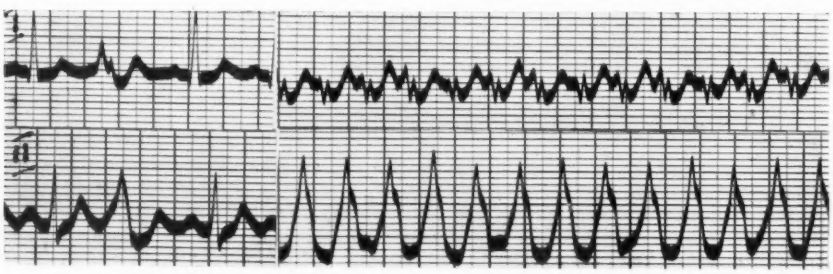


FIG. 18.—Case 25. Leads I and II. Ventricular extrasystoles are shown during normal rhythm. The ventricular complexes during the paroxysms are sufficiently similar to those of the extrasystoles during normal rhythm to indicate the ventricular origin of the tachycardia.

appeared to be perfectly normal. B.P., 130/80; EC. showed that the attacks were ventricular in origin.

Case 26 (Fig. 11). A woman, aged 21, was admitted to the hospital for investigation of her thyroid. She had lost weight and had started to have attacks of rapid heart action six weeks previously. EC., paroxysmal ventricular tachycardia. No organic disease was discovered. Her subsequent history is unknown.

Case 27 (Fig. 2). A woman, aged 32, had for the past fourteen years had spells of rapid regular racing of the heart, lasting up to 52 hours. The EC. showed a short P–R interval, a widened QRS complex, and runs of ventricular tachycardia. Examination suggested the presence of an interventricular septal defect. She still has frequent attacks of tachycardia but is otherwise well.

Five cases with Paroxysmal Tachycardia of Doubtful Origin

Case 28 (Fig. 3 A). A man, aged 40, had had attacks of paroxysmal tachycardia for 25 years, almost constant at times. Treatment had little effect. Physical examination showed nothing abnormal.

Case 29 (Fig. 3 B). A man, aged 39, was first seen 16 years ago when he gave a history of having developed pain, dyspnœa, and vomiting after a long quick run. B.P., during the attack, 70/55, and pulse rate 210. Examination was otherwise normal. He is at present well, suffering only an occasional bout of palpitation.

Case 30 (Fig. 3 C). A man, aged 33, was admitted in an attack of tachycardia, paroxysmal in type. Physical examination was negative. Follow-up study ten years later revealed that he had died, but the details and date are unknown.

Case 31 (Fig. 5). A man, aged 25, had developed tachycardia seven years previously while playing a strenuous game of tennis. This attack lasted three days before it was stopped by quinidine. Examination was normal. He has had no more attacks since that time, and is extremely fit and active.

Case 32. (Fig. 3 D). A man, aged 26, was admitted to the hospital following a collapse during a paroxysm of tachycardia. He was also suffering from acute gonococcal urethritis. Physical examination also revealed well-marked mitral and aortic rheumatic heart disease.

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PARTIAL HEART BLOCK WITH DROPPED BEATS

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Partial heart block with dropped beats is, in my experience, generally found during acute infections or after too much digitalis. This is such a contrast with the ætiology of complete heart block, that it seems worth analysing a series of cases with all degrees of heart block, to see what association there is between partial block with dropped beats and complete block, and to define more precisely the conditions producing the former. The second part of the paper deals with the progressive changes found in the P–R intervals before and after the dropped beat.

I. Clinical Observations

There were 29 patients who had partial heart block with dropped beats without any higher degree of block. This was nearly one eighth of the total number ; but the condition is noticed less frequently than this would suggest, because generally it persists for a few days or weeks only, while in other types the degree of block is likely to be of long duration so that the patient is seen again, perhaps over a long period.

The occurrence of dropped beats is nearly always very transient, and most often due to an acute infection or to treatment with digitalis. The 11 cases in this last group have already been discussed (Campbell, 1942) and in 6 of them infection was an additional factor. In the 18 where it was not due to digitalis, 6 had acute rheumatism and 6 had other infections, most often acute tonsillitis that did not appear to be a manifestation of rheumatic fever. Thus, 12 of the 18 had active infection at the time : most of these were young adults. In the remaining 6, who were nearly all older patients, there was no evidence of an active infection, and even when the condition was transitory it seemed to be a stage in their chronic disease or was observed at times without any obvious reason.

There were a further 9 cases, making 38 in all, where there was at one time partial heart block with dropped beats, and at other times a higher degree of block, such as 2 : 1 or even complete block (see Table I). Only 2 of these belonged to the group with active infection, and 7 to the older group with chronic disease.

TABLE

Ætiology of Cases with Dropped Beats

Ætiology	Partial heart block with dropped beats only		Partial block with at other times higher grades of heart block	Total
	caused by digitalis	other causes		
Acute rheumatism ..	2	6	1	9
Other acute infections, mainly tonsillitis ..	1	6	1	8
Chronic myocardial disease*	8†	6	7	21*
Total number of cases ..	11	18	9	38

* Of the 21 cases, 3 were rheumatic ; the remainder in each group were almost equally distributed between (*a*) hyperpiesia, (*b*) coronary atheroma, and (*c*) heart failure or a large heart without proof of (*a*) or (*b*).

† Infection was an additional factor in 3 of these.

Ætiological Factors

1. *Active infection.* (*a*) *Acute rheumatism.* There were nine patients in this group. They did not seem to be quite representative of average cases of this disease, as a boy of 18 with a typical first

attack (Case 13) was the only one under 24 years of age. Three had pericarditis. The first started with pericarditis and partial heart block and developed aortic incompetence (Case 1). The second had pericarditis and joint changes that were in some ways less like rheumatic than rheumatoid arthritis, and no evidence of valvular disease (Case 21). The third developed complete heart block at the start of a recurrent attack of theumatic fever (she already had aortic incompetence) ; this lasted for a week and was followed by partial block, sometimes with dropped beats, sometimes 2 : 1, and this persisted for three months : in spite of this she made an excellent recovery and was in good health twelve years later with very little change in these intervening years, although she did a fair amount of work running her father's house (Case 113, Campbell, 1931). Another man, aged 51, also escaped without permanent changes after a classical severe attack—the first and only other attack having been 38 years before (Case 22).

There was nothing special to say about the remaining patients, all of whom had established valvular disease before the attack in which dropped beats were observed, except that in three the recurrence causing the dropped beats seemed in other ways a trivial one. The cases are summarized in Tables II and III, and those caused by digitalis in Table II of the previous paper.

As has been noted in other series, the aortic valve was affected more frequently than in an average series of rheumatic cases, the figures being : aortic disease, 2 cases ; aortic and mitral disease, 1 ; mitral disease, 4 (in 2 the mitral involvement was slight) ; no valvular disease, 2 cases.

TABLE II

DROPPED BEATS, BUT NO HIGHER DEGREE OF HEART BLOCK (18 CASES) *

Case No.	Sex and Age	Diagnosis	P–R interval		
			with dropped beats	without dropped beats†	after recovery
		Acute rheumatism			
1	m.25	Rheumatic pericarditis ; developed aortic incompetence	—	—	0·19
10	f.30	Aortic and mitral disease ; recurrent rheumatism	0·28–0·40	0·32	0·21
13	m.18	Acute rheumatism (first attack)	0·24–0·41	—	0·16
15	f.34	Mitral systolic murmur; recurrent rheumatism	0·24–0·32	0·28	0·18
21	m.30	Pericarditis and acute arthritis	0·45–0·48	0·47	0·18
22	m.51	Acute rheumatism (second attack) ..	—	0·34	0·16
		Other infections			
5	f.18	Acute tonsillitis; early tuberculosis of lung	—	0·32	0·21
17	f.23	Tonsillitis; previously erysipelas	—	0·32	0·16
23	f.21	Quinzy and hyperthyroidism	0·20–0·40	0·36	0·20
25	f.45	Thyrotoxicosis; acute tonsillitis	0·28–0·38	0·26	0·18
29	m.50	Recurrent dysentery; later slight sore throat	0·35–0·42	0·42	(0·28)
20	m.29	Tuberculosis of lungs; nephritis; enlarged heart; dextrocardia	0·29–0·56	0·56	—
		Chronic Rheumatic			
7	m.22	Mitral stenosis ; ? gonococcal myocarditis	0·20–0·36	0·36	—
14	m.52	Rheumatic aortic incompetence	0·28–0·44	0·28	—
		Myocardial			
3	m.61	Atherosclerosis; B.P. 180/100	0·25	0·25	—
6	f.70	Cerebral thrombosis; heart failure ..	0·24–0·38	0·24	—
16	m.80	Coronary atheroma	—	0·30	—
24	m.66	Enlarged heart; B.B.Bl.	0·24	0·24	—

* Cases where the dropped beats were due to digitalis have not been included here (see Table II of the previous paper).

† In most cases the P–R interval when the heart block is latent is almost the same as the first P–R with a response at a time when there are dropped beats, but in cases 7, 20, 21, 23, and 29 it is almost the same as the last P–R interval before the dropped beat.

TABLE III

CASES WITH DROPPED BEATS AND AT OTHER TIMES A HIGHER GRADE OF BLOCK (9 CASES).

Case No.	Sex and Age	Diagnosis	P–R interval			Presence of complete heart block
			with dropped beats	without dropped beats *	with 2 : 1 heart block†	
		Acute rheumatic				
113	f.25	Acute rheumatic carditis; aortic incompetence	0·18–0·25	0·16 ‡	0·19	+
		Other infections				
109	m.55	Congestive failure; ? infective endocarditis	0·20–0·30	0·17	0·19	—
		Chronic rheumatic				
107	f.42	Rheumatic mitral endocarditis ..	0·29–0·40	0·28	{ 0·24 0·28 }	+ (once)
		Myocardial				
103	f.66	High B.P. (250/115)	0·21	0·21	0·21	+
104	m.64	Early congestive heart failure ..	0·29–0·41	0·34	0·31	?+ (once)
110	f.62	Coronary atheroma	0·23–0·28	0·23	0·23	—
112	f.72	High B.P. (175/90)	0·24–0·32	0·29	0·23	—
117	m.56	Enlarged heart nephrectomy for tumour	0·26–0·30	—	0·26	—
119	m.49	Coronary disease; ? atheromatous, ? syphilitic	0·28–0·40	0·40	0·40	+

* The P–R interval of latent block is almost the same as the first P–R interval with a response, except in Cases 104, 112, and 119.

† The P–R interval with 2 : 1 heart block is almost the same as the first P–R interval with a response, except in Case 119.

‡ This was obtained at a later period, after recovery.

1 (*b*). *Other active infections, mostly tonsillitis.* There were eight cases in this group. Two of them were specially important because the dropped beats were caused by ordinary attacks of tonsillitis in patients with normal hearts. They are therefore described more fully below. It has been suggested that a prolonged P–R interval in a young person is pathognomic of acute rheumatism, but there was not the slightest reason to suspect that these patients or their attacks of tonsillitis were rheumatic.

In three others, throat infections and thyrotoxicosis were associated (see p. 58). A sixth had congestive heart failure with some infection, probably infective endocarditis (Case 109). The seventh, having had bacillary dysentery several years before, was recovering from a relaspe and had a slight sore throat soon after the dropped beats had been found rather unexpectedly (Case 29). The eighth had advanced tuberculosis of the lung and a large white kidney, and died three weeks later with suppurative parotitis (Case 20).

Case 17. A nurse, aged 23, had erysipelas and was away for five weeks. She worked for three weeks with some tachycardia and then went to bed with a sore throat. Her temperature did not reach 100, but after a few days dropped beats were suspected clinically, and she was sent for a cardiogram which showed a P–R interval of 0·32 sec. Within three weeks it had fallen to 0·16 sec.

She has been under regular observation for ten years since and has never been off work or noticed any rheumatic or cardiac symptoms ; she may be a trifle short of breath, but no more than would be expected from her weight. There have been no physical signs in her heart, the P–R interval has remained at 0·16 sec., and neither before nor since have there been any symptoms suggestive of rheumatism.

Case 5. A girl, aged 18, was admitted for a sore throat, malaise, and a pain in the right shoulder that had been present for five weeks. Her temperature was 101, but became normal in three days and her general condition quickly improved. There were some doubtful signs at the right apex, but after X-ray and sputum examination tubercle was exluded, wrongly, as was found later. Her heart rate on admission was 85, but fell to about 44–56 during the first week and dropped beats were

diagnosed. On the tenth day the P–R interval was 0·29 sec., inreased to 0·32 after exercise. She was not sent for a cardiogram again and was discharged apparently well after a few weeks. She was written for four months later, when she looked and felt well and the P–R interval was 0·21 sec.; but when written for again after two years she was found to be in hospital with bilateral tuberculosis and died soon after.

2. *Chronic heart disease.* There were thirteen in this group, excluding those where the dropped beats were caused by digitalis. On the whole they were older patients, mostly about 60. In this group, too, the dropped beats were generally transient. But in contrast with many of the younger patients, the underlying heart disease remained unchanged, and nearly always there was some permanent heart block ; sometimes this was only latent, but often it was 2 : 1 or a higher grade of block. Complete heart block and Stokes-Adams attacks were indeed not uncommon in this group. These points are dealt with more fully and the findings contrasted with those in the younger group, where the dropped beats were due to active infection, in the discussion that follows.

Discussion

Age incidence. Excluding the cases caused by digitalis where all ages and types of disease were found, there was a complete contrast between the two groups of those with active infection and those with chronic heart disease. The average age of the fourteen patients with infections was 32 years ; all were between 18 and 51, and all but three between 18 and 34. The thirteen without active infection were nearly all over 60. The average age of nine of them was as high as 67, and the average of all thirteen was only kept as low as 59, because of two patients, aged 22 and 42, with mitral disease, one, aged 49, probably syphilitic (Case 119), and one, aged 52, with rheumatic aortic incompetence. The patient, aged 22, was exceptional in many ways and the dropped beats may have been due to a recurrent infection if his lesion really was a rheumatic mitral stenosis, because during several years when he was under observation with latent heart block this was the only time he had dropped beats, and later treatment with digitalis seemed more liable to change the rhythm to auricular fibrillation than to dropped beats. There was no rheumatic history but a very persistent gonococcal prostatitis (Case 7).

The transient nature of dropped beats. In the patients of both these groups the dropped beats were very transient and generally lasted for some days only. Naturally this was so in the cases where they were caused by infections or digitalis treatment, though in Case 113 the partial block was unusual by lasting for as long as three months.

More unexpectedly, it was nearly as transient in the older cases. Many of these were seen regularly or intermittently for five or six or even for ten or twelve years ; and yet it was rare to have more than one or two plates with dropped beats unless these were taken about the same time. There was no patient with any reasonable expectation that dropped beats would be observed on any particular occasion he might be seen. The nearest approach to this was a doctor, aged 80, with mild anginal symptoms who said that he had noticed dropped beats, sometimes one in four, sometimes one in twenty, for about six years ; I expected to find extrasystoles, but as the P–R interval was 0·30 sec. on both occasions he was seen, I think that he was correct, though I was not lucky enough to record any dropped beats (Case 16).

Prognosis, especially as regards the persistence of block. In the younger group due to infections, the heart block was often as transient as the dropped beats, so that the P–R interval returned to normal and the patient made a very good recovery with a heart that was nearly if not quite as good as before. This was specially true of the cases with uncomplicated tonsillitis and often of those with acute rheumatism.

The nurse with dropped beats after tonsillitis may be quoted, as within a few weeks her heart was thought to be normal and her history during the subsequent ten years bears this out (Case 17, see p. 57). She was the patient whose heart could with the greatest certainty be called normal, though there were others who seemed to make a complete recovery ; several even of the rheumatic patients made a surprisingly good recovery, for example the young woman quoted with transient complete heart block who is still in good health twelve years later. The degree of recovery of the P–R intervals is well shown in Table II.

The only exceptions to this generally good outlook were the cases in which the infection was so severe that the patient died while still in the acute stage of his illness. The occurrence of heart block in cases where tonsillitis and hyperthyroidism were associated seemed of grave significance. There were three such patients, one having slight signs of hyperthyroidism and developing dropped beats after treatment with strophanthin when her septic tonsils had been removed (Case 28), one having a severe quinzy and slight evidence of hyperthyroidism (Case 23), and the other having exophthalmic goitre with partial heart block and dropped beats following an attack of tonsillitis (Case 25). The

last two were among the small number of patients who died soon after dropped beats were observed ; the former died with a patchy myocarditis, and the latter died at home and was said to have had a pulse rate of 20 before her death (she was not placed in the group with complete heart block as this only included proved cases).

By contrast the older group generally had a long P–R interval or a higher degree of block permanently, even though the dropped beats were only observed for a time. Furthermore, there was permanent heart disease as the underlying cause : e.g. high blood pressure and atherosclerosis (Case 3), an enormous heart and bundle branch block (Case 24), atherosclerosis and a P–R interval of 0·30 sec. in a man of 80 (Case 16), congestive failure after a probable coronary thrombosis (Case 6), and so on ; and as might be expected the prognosis are mainly dependent on this. Actually only five of the thirteen died while they were under observation, but unfortunately less care was taken to keep in regular touch with these older patients.

Another difference was that the younger group generally had no higher degree of heart block than the dropped beats, while this was quite common with the older group. Only three of the seventeen in the younger group had higher degrees of block : viz. the girl who had complete heart block followed by various grades of partial block during her acute rheumatism, and recovered without even latent heart block (Case 113) ; a woman of 45 with hyperthyroidism and tonsillitis who insisted on leaving hospital soon after her dropped beats had been recorded and died at home a few weeks later, probably with complete heart block (Case 25) ; and a man, aged 50, with congestive failure probably due to infective endocarditis, who had latent block, 2 : 1 block, and dropped beats within a few minutes on the same cardiogram (Case 109).

By contrast, rather more than half the older group with chronic heart disease had 2 : 1 heart block ; four of these were seen with complete heart block also, and one of them had a history of Stokes-Adams attacks. In addition, two of those, in whom neither 2 : 1 nor any higher degree of block was observed, gave a history (one certain and one doubtful) of Stokes-Adams attacks. A woman of 42 with rheumatic mitral disease may be taken as an example that the higher degree of block was the more usual finding in this group. Seen about twenty times in the course of five years, there was only one record with dropped beats, though latent block without dropped beats was seen several times in 1933 and in 1936 : most often there was 2 : 1 heart block, though sometimes this was changing to latent, and once there was complete block. Her symptoms had started with one Stokes-Adams attack and she died suddenly six years later, presumably in another such attack (Case 107). Or again an elderly woman with high blood pressure who had dropped beats the first time she was seen : subsequently until her death six months later she generally had complete but sometimes 2 : 1 heart block (Case 103).

In conclusion, partial heart block with dropped beats was very transient. In two thirds of the cases it was due to acute infections or to digitalis treatment ; rheumatic fever was the most common, and tonsillitis the next most common infection. When it was due to infection, the patients were nearly all young, between 20 and 34, and generally made a very good recovery. In one third there seemed no obvious precipitating cause of the dropped beats. These were older patients, generally over 60, with chronic heart disease that was often serious, and in half of them a higher degree of heart block such as 2 : 1 was the usual rhythm.

II. The Mechanism of Dropped Beats

In 30 of the 38 cases the diagnosis was made on electrocardiographic evidence, so that the P–R intervals could be measured; in the other 8, it was made by the clinical observation of dropped beats and a long P–R interval in the cardiogram. These will be considered in two groups—a small number with no progressive increase of the P–R interval and a larger number with progressive lengthening.

Dropped Beats with no Previous Lengthening

In 4 of the 30 cases the dropped beats occurred without any significant lengthening of the preceeding P–R interval. Lewis (1925, p. 177) states that this type of heart block due to " depression of excitability " was first described by Hay (1906) : his case showed 2 : 1 heart block with a normal a–c interval, and also the change from this to normal responses without any change in the a–c interval: there were no isolated dropped beats. This same type is, however, found in cases with dropped beats, the P–R interval being unchanged before and after the dropped beat, though generally prolonged.

The four cases of this type were an elderly woman with high blood pressure, who also showed 2 : 1 heart block, the P–R interval with all rhythms (latent and 2 : 1 block and dropped beats) being 0·21 sec. (Case 103): a man, aged 61, with high blood pressure, whose P–R interval was 0·25 sec.

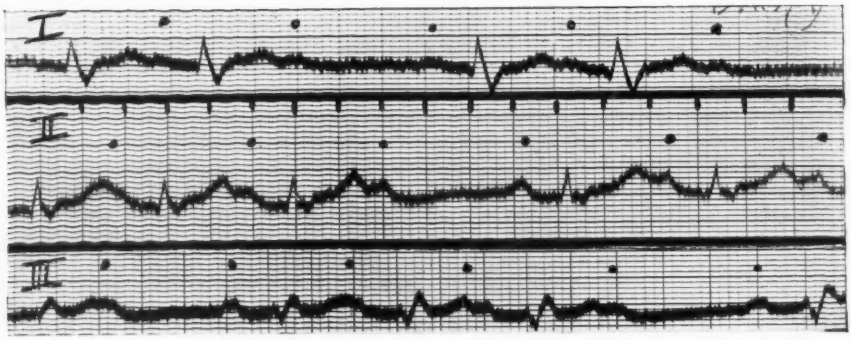

FIG. 1.—Fairly frequent dropped beats without any progressive lengthening of the P–R intervals which are all about 0·25 sec. John Hay's depression of excitability. From an elderly man with atherosclerosis and high blood pressure. Case 3.

In this and succeeding figures the auricular waves have been marked with dots (.), and the time-marker rulings have been inked to show up fifths of a second.

whether he had dropped beats or only latent heart block (Case 3, Fig. 1: a man, aged 66, with a large heart and bundle branch block; whose irregular heart was generally caused by extrasystoles and sino-auricular block, but sometimes by dropped beats after his extrasystoles, the previous P–R intervals remaining unchanged at about 0·24 sec. (Case 24); and a man, aged 30, with pericarditis and acute arthritis, where the position was less definite, the P–R interval often remaining constant at 0·48 for many beats before one was dropped, but shortening a little to 0·45 sec. afterwards (Case 21, Fig. 2). Another case, seen recently, was a woman of 80 whose P–R interval was 0·26 (and had

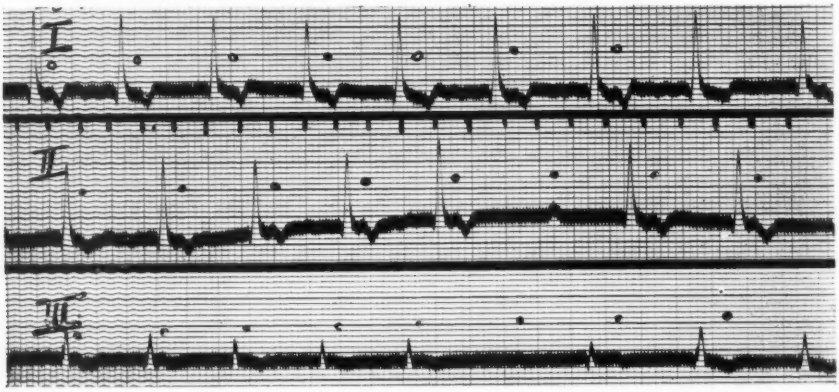

FIG. 2.—Occasional dropped beats interrupting very long P–R intervals which are little changed. Those before the dropped beat were all 0·48 sec. and the one after was 0·45 sec. From a young man with pericarditis and rheumatism. Case 21.

been the same six months before when she had no dropped beats); she had also wide QRS waves and almost the picture of bundle branch block. Four of these five patients were elderly and of the type where complete heart block would not be an unexpected finding.

Other cases suggested that changes and intermediate types between this group and the more usual one with progressive lengthening of the P–R intervals (Wenkebach's periods) are not uncommon, e.g. a man where four or five P–R intervals before the dropped beat had a constant length of 0·44, but one as short as to 0·28 sec. after the dropped beat (Case 14, Fig. 3). Another patient (Case 11), in whom the usual sequence of events was 0·24, 0·42 sec., d.b., etc., sometimes showed three or four final responses at a constant P–R of 0·42 sec. before the dropped beat.

Another with acute rheumatic carditis (Case 113), who showed all stages from one dropped beat after seven responses to 2: 1 heart block, gave a sequence that resembles this to some extent in that

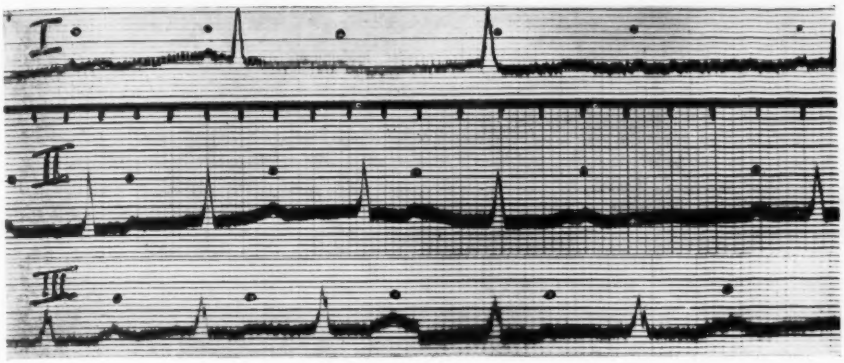

Fig. 3.—A dropped beat after a long series of unchanged P–R intervals, each being 0·44 sec., but with much shortening of the P–R interval (0·28 sec.) after the dropped beat. From a man with rheumatic aortic incompetence. Case 14.

the increase from 0·18 to 0·22 sec. during eight beats before a dropped beat seemed to remain steady in the middle period, e.g. 0·18, 0·20, 0·21, 0·21, 0·21, 0·21, 0·22, d.b. Inevitably as the number of responses before a dropped beat grows greater, the change in succeeding P–R intervals must be less, but one of the longest we have measured with a dropped beat after eight responses was: 0·28, 0·32, 0·32, 0·33, 0·34, 0·37, 0·39, 0·40, d.b. (Case 10).

A young woman in whom dropped beats were only noted after vagal pressure in the neck (Case 23) may throw some light on the mechanism involved. Though at times her response was 0·20, 0·40, d.b., etc., at other times it might be: 0·32 (6 times), 0·36, d.b.; or 0·20, 0·29, 0·34 (4 times); possibly because the effective pressure on the vagus was not sufficient to produce the first more usual response.

Dropped Beats with Progressive Lengthening

Omitting the 4 cases that gave dropped beats with no previous lengthening, there were 26 left to study the rate of lengthening of the P–R interval before the dropped beat. In some of these, various responses (e.g. 3 : 2, 4 : 3, 5 : 4, etc.) were observed (Cases 2 and 113 gave the most complete series for comparison in a single case); in others the responses were all of the same type. Naturally 3 : 2 heart block was seen most often (18 cases) and then 4 : 3 block (9 cases).

3 : 2 *Heart block*. This was observed in 18 cases; in a few there was only a single record, but in the great majority there were at least three or four measurements, which would help to eliminate chance errors.

There were great variations in the length of the P–R intervals in different patients, without any obvious relationship to the degree of heart block or to the type of diseased heart. Thus, the first P–R interval after the dropped beat might be a little below 0·20 sec. or as long as 0·30; the last before the dropped beat might be as short as 0·25 or as long as 0·40; and the difference between the two P–R intervals might be as much as 0·20 or as little as 0·10 or sometimes even 0·05 sec. These figures are given more accurately in Table IV; they were very much the same in the different grades of heart block. It was rather surprising to find this, as one might expect that where the first P–R interval was 0·28, a dropped beat would be likely to occur sooner (i.e. after fewer responses) than in a case where it was only 0·20 sec.; and that the difference between the first and last P–R interval would be

TABLE IV

Variation in First and Last P–R Interval after and before a Dropped Beat

Grade of heart block	First P–R	Last P–R	Difference between first and last P–R
3 : 2	0·18 to 0·29	0·26 to 0·42	0·046 to 0·20
4 : 3	0·18 to 0·29	0·25 to 0·41	0·07 to 0·17
5 : 4	0·17 to 0·29	0·27 to 0·43	0·045 to 0·21
6 : 5	0·19 to 0·28	0·26 to 0·43	0·07 to 0·16
7 : 6	0·18 to 0·28	0·23 to 0·44	0·045 to 0·22

much greater where there were six responses before a dropped beat than when there were only two. It suggests, as do other findings, that more than a depression of conductivity is concerned in the production of dropped beats.

It was quite common for the P–R interval to lengthen to 0·40 or even 0·44 sec., as will be seen from figures of this magnitude occurring in each grade of heart block in Table IV. Exceptionally, however, as in a man who died with tuberculosis of the lungs and nephritis, it lengthened more than this, from 0·29 to 0·56 sec.; later as his general condition became worse the heart rate quickened to 100, but no further cardiogram was obtained (Case 20, Fig. 4).

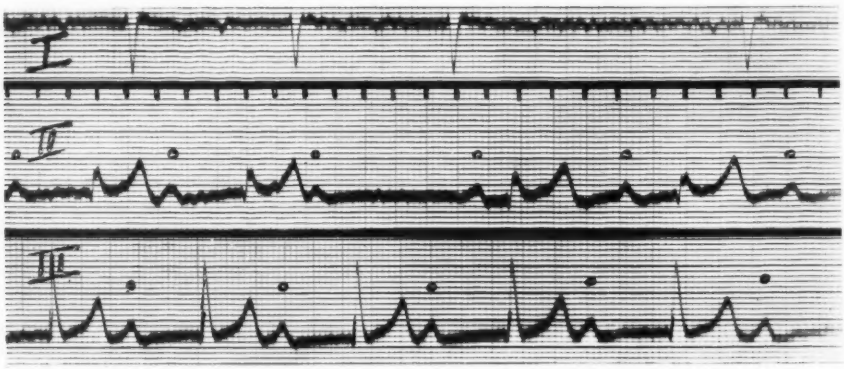

FIG. 4.—Unusually long P–R intervals, 0·56 sec., sometimes very regular as in lead III, sometimes shortening considerably to 0·29 sec., after a dropped beat as in lead II. From a man with tuberculosis, nephritis, and dextrocardia. Case 20.

I have not been able to find that any type of patient or type of heart disease is specially prone to fall into the groups with the longer or shorter P–R intervals. Taking the cases of any one grade of heart block there was some slight tendency for a short first P–R interval to be followed by a relatively short last P–R; e.g. if the cases were averaged in three groups according to the length of the first P–R interval the sequences were 0·19, 0·32, d.b.; 0·22, 0·35, d.b.; and 0·25, 0·36, d.b. But there was no close correspondence and there were many exceptions.

The average figure for the whole series (allowing a little extra weight to the cases where there were many records) was 0·227, 0·347, d.b., etc., but an arithmetical average without any weighting would have made little difference as this would have given the sequence 0·232, 0·345, d.b., etc.; subsequent figures were therefore obtained by the arithmetical average.

4 : 3 *Heart Block*. This was observed in nine cases and in most of them there were several measurements. There was again great variation in the first and last P–R intervals and in the difference between them, these covering about as wide a range as with 3 : 2 heart block. Lewis (1925, p. 177) states: "It is the rule for the dropped beat to be foreshadowed by progressive lengthening of the P–R interval. The increase of the second interval over the first is greater than the increase of the third over the second, or more generally: as the P–R interval increases the rate of increase in the P–R interval diminishes and the ventricular rate consequently quickens slightly." Six of the nine cases agreed with this, giving an average sequence P–R, 0·236, 0·304, 0·341, d.b., etc., the increment being 68 and 37, but in many of them the difference was not great. One (Case 13) showed this in an extreme form (Fig. 5) the sequence being 0·24, 0·37, 0·41, d.b., etc. In the seventh the intervals were equal and in the eighth the sequence was 0·18, 0·21, 0·25, d.b. The ninth (Case 2) showed the reverse relationship, the sequence being 0·25, 0·31, 0·39, d.b. The average figure for all nine cases was 0·238, 0·297, 0·340 sec., d.b., the first increment being greater than the second in the porportion of 59 to 43.

5 : 4 *Heart Block*. There were five cases, all but one with two or more records that could be measured. There was the same variation in the first and the last P–R intervals (see Table IV). The average figures were 0·239, 0·281, 0·314, 0·349, d.b., etc., and again the difference between the first two was the greatest but not to any very marked extent, the figures being 42, 33, 35. Taking the individual figures they were more evenly spaced than in the other groups, but probably this was no more than chance. It was, however, significant that nearly all the cases in this group and the groups with higher grades of heart block were due to digitalis treatment or to acute infections.

FIG. 5.—Generally 3 : 2 heart block (P–R, 0·25, 0·37, d.b., etc.), but at the end of lead III, 4 : 3 heart block with Wenckebach's periods : P–R, 0·24, 0·37, 0·41 sec., d.b., etc. The amount by which the first increment exceeds the second is here exceptionally large, though it is usual for the first increment to be larger than the second or subsequent ones. From a young man with rheumatic fever. Case 13.

6 : 5 and 7 : 6 *Heart Block*. Naturally there were fewer examples of these types and much stress cannot be laid on the average figures as they were only based on four and three cases respectively. There was much the same range in the first and last P–R intervals and in the difference between them as in the higher grades of heart block discussed. The average sequence of P–R intervals is shown in Fig. 6 and in Table V with the averages of the other groups. In both these groups the increment

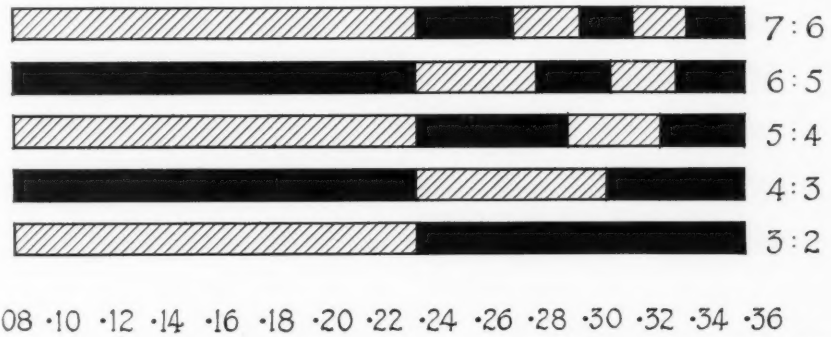

FIG. 6. Diagram showing the length of the successive P–R intervals with different grades of heart block. Drawn from the smoothed figures given in Table VI.

was greatest between the first and second intervals, but after that the increment seemed to be fairly regular, the figures being 37, 22, 21, 25 (6 : 5); and 41, 22, 21, 20, 23 (7 : 6). In the last three groups there seemed a slight tendency for the last increment to be a little higher than any of the other figures except the first; in some individual cases it seemed to be more noticeable but rather inconstant.

DISCUSSION

The average figures for the P–R intervals with different grades of heart block with dropped beats (d.b.) are shown below in thousandths of a second :

TABLE V

3 : 2 heart block	227, 347, dropped beat.
4 : 3 ,, ,,	238, 297, 340, d.b.
5 : 4 ,, ,,	239, 281, 314, 349, d.b.
6 : 5 ,, ,,	232, 269, 287, 308, 333, d.b.
7 : 6 ,, ,,	226, 267, 289, 310, 330, 353, d.b.

Wenkebach (1904) discussed this gradual lengthening of the a–c interval in his book on arrhythmia of the heart; he says " the interval is shortest at the first contraction after the pause, it is considerably longer at the second, and increases only a little more in length with succeeding systoles." He spoke of Luciani's periods and also described similar results obtained by Englemann in experiments with cardiac muscle; from this he deduced that it was due to a fundamental property of cardiac muscle and not to some special property of the fibres forming the block at the A-V groove.

Of two series of figures he quoted, chosen at random, 0·235, 0·30, 0·322, 0·345, 0·365, d.b.; and 0·23, 0·37, 0·40, 0·43, 0·45 sec., d.b.; the former is near to the average found in this series and the latter is an instance where the first increment exceeds the other increments by much more than usual. Basing his arguments on his own work (*Über den regelmässig intermittierenden Puls*, 1899), and especially on that of Mackenzie, he argued that clinical heart block is a defect of conductivity. Partly as a result of his work, this is now so widely recognized that the difficulty of accepting it as the whole explanation is sometimes forgotten—a point which will be discussed later.

To return to the figures obtained in this series: the first P–R interval averaged 0·232 sec. and the last 0·345 sec. As some were above and some below this without any regular graduation, one can get a better comparison of the intermediate figures by adjusting all the first figures to 230 and all the last to 350 with corresponding adjustments of the other figures. There will still be irregularities due to errors and the small sampling, but by plotting out the figures and drawing smoothed curves one gets a more regular series of figures which are probably a better approximation to the truth; these are shown below.

TABLE VI.

3 : 2 heart block	230, 350, dropped beat.
4 : 3 ,, ,,	230, 300, 350, d.b.
5 : 4 ,, ,,	230, 286, 319, 350, d.b.
6 : 5 ,, ,,	230, 275, 303, 327, 350, d.b.
7 : 6 ,, ,,	230, 266, 292, 312, 332, 350, d.b.

The first group of figures were submitted to Professor W. A. H. Rushton of Cambridge with the request for a mathematical formula covering their relationship. He very kindly considered the problem and wrote that the following formula has no arbitrary constants, is easy to compute, and seems to fit on the whole pretty well. If the grade of heart block is N+1 : N, the P–R interval for the *n*th beat after a dropped beat is given by T in thousandths of a second, where

$$T = 250 + 120\frac{n-1}{N} - \frac{20}{10^{n-1}}$$

The corresponding figures calculated from this formula agree fairly well with the observed figures, except in the case of the second beat with 3 : 2 heart block where the calculated figure is much smaller; they are :

TABLE VII

3 : 2 heart block	230, 308, (370)
4 : 3 ,, ,,	230, 288, 330, (370)
5 : 4 ,, ,,	230, 278, 310, 340, (370)
6 : 5 ,, ,,	230, 372, 298, 322, 346, (370)
7 : 6 ,, ,,	230, 268, 290, 310, 330, 350, (370)

It thus appears from Professor Rushton's figures the beat is dropped when the P–R interval would have become as long as 0·37 sec. Looking at the same problem in a slightly different way I had concluded that there was a response when the P–R interval was 0·35 sec., but not when it reached a longer time than this. One must remember that these are *average* figures and that in individual cases they may be a good deal higher or lower.

In 15 cases it was possible to make a comparison between the P–R interval at the times when there were and when there were not dropped beats. With the dropped beats, the average P–R interval increased from 0·26 sec. to 0·37 sec.: without the dropped beats, it was 0·30 sec., an intermediate figure nearer to the P–R interval of the first response after the dropped beat. Actually, in 7 cases it was the same as the P–R interval of the first response, and only in 3 cases was it the same as the P–R interval of the last response before the dropped beat.

In 9 cases (Table III) one could also compare the P–R interval with 2 : 1 heart block. The average figures were : first response after the dropped beat, 0·24; last response before a dropped beat, 0·34; latent heart block with no dropped beats, 0·27; and 2 : 1 heart block, 0·25 sec.

It is interesting that the P–R interval with latent heart block with no dropped beats, the P–R interval of the first response after a dropped beat, and the P–R interval with 2 : 1 heart block should all be so close—0·24 to 0·27 sec. in these cases.

The correspondence of these three, both in average and in individual figures, and our observations that whatever the grade of heart block—whether there are dropped beats after two responses or after six or seven—the first P–R interval after the dropped beat averages 0·23 sec. and the last before the next dropped beat 0·35 sec. must be taken into account in any explanation of heart block.

The real difficulty has always been to explain why in one case a P–R interval of 0·35 sec. gets no longer and is regularly followed by a response, and yet in another case a P–R interval that is shorter or nearly normal lengthens till it reaches a stage where a beat is dropped.

If the higher grades of heart block were always associated with the very long P–R intervals such as 0·35–0·40 sec., and the lower grades with shorter P–R intervals such as 0·25–0·30 sec., one could look on the defect of conductivity as the whole or almost the whole explanation. But when it is possible to have a P–R interval of, say, 0·24 sec., with regular responses and no dropped beats or a P–R interval of the same duration with dropped beats or with 2 : 1 block, a second factor must also be involved.

It seems that depression of excitability, the main explanation in the cases described by Hay, is also concerned in all these other cases. The separation of the function of cardiac muscle into its four divisions, of which conductivity and excitability are two, has been criticized, but clinical study of heart block suggests that these two at any rate are both involved in the production of most cases of heart block. Probably the same factors that affect conductivity also affect excitability of the ventricle, and the grade of heart block depends on the interaction of these two.

Summary and Conclusions

Partial heart block with dropped beats is nearly always transient, so that it is rare to find a patient in whom this rhythm can be expected as a usual or even as a common finding.

At one time or another it was observed in nearly one sixth of a series that included all types of heart block, but this gives an exaggerated idea of its frequency because it was generally transient and of short duration.

In two thirds of the cases (25 out of 38) there was a known cause, active infection or treatment with digitalis. In 14 the cause was an acute infection, in 5 it was treatment with digitalis, and in 6 both causes combined. As would be expected, acute rheumatism was the most common infection (9 of 20 cases) ; but tonsillitis, without any suggestion that it was rheumatic, was often found.

The patients with dropped beats due to infections were mostly between 18 and 34 years of age. The outlook in this group was surprisingly good and the patient often recovered even to the stage of a normal P–R interval. As an exception the simultaneous association of tonsillitis and hyperthyroidism with dropped beats seemed of grave significance.

In the remaining third (13 cases) there was chronic heart disease and no very obvious reason why the dropped beats should have been found at the time they were, for here, too, they were generally transient. These were older patients, nearly all well over 60 years of age: all had chronic heart disease; high blood pressure and coronary atheroma were each the ætiological factor in one third, and in the remaining third there was myocardial disease without evidence of either of these factors.

In addition, some degree of heart block generally remained in the group of older patients, half of them having 2 : 1 heart block as a common or as their most usual rhythm. This was not so with the younger patients. Complete heart block also was uncommon in the group of younger patients with infections, but was present at some time in about one quarter of the older group. The regular sequence of dropped beats, 2 : 1 heart block, and finally complete heart block was observed, but was rare.

The length of the P–R intervals was also studied. Progressive lengthening, but with a decreasing increment, was the rule, the increase of the second P–R interval over the first being much larger than the subsequent increases. There were, however, exceptions. In about one eighth of the cases with dropped beats, these came without any gradual lengthening of the P–R interval (Hay's depression of excitability); these patients were mostly older ones with chronic heart disease.

For each grade of heart block up to a dropped beat after six responses, there were enough records to give some average figures, which have been shown in Table V and Fig. 6 and can be given more shortly as

3 : 2 heart block ; 0·23, 0·35 sec., dropped beat.
4 : 3 „ „ 0·23, 0·30, 0·35, d.b.
5 : 4 „ „ 0·23, 0·285, 0·32, 0·35, d.b.

It must, however, be repeated that these are only the average of figures that varied widely in the different cases. It is strange that the average and the range of the P–R intervals between the first response after and the last response before the dropped beat should be so constant, whether there is one dropped beat to 3, 4, 5, or 6 responses. This finding and some of the other points that have been discussed suggest that the defect of conductivity is generally the condition which makes heart block likely, but that something else, probably excitability, decides if there will be block and, if so, of what grade it will be.

I should like to express my thanks to my colleagues at Guy's Hospital and at the National Hospital for Diseases of the Heart for allowing me to continue observations on some patients who were under their care. Without the help of Dr. S. Suzman as Clinical Assistant and Mr. F. H. Muir as technician, it would not have been possible to keep in touch with so many patients or to get so much information about patients who were generally first seen during busy routine sessions. Such work has obvious limitations and in some directions more could have been found out in a few days by intensive experimental observations on one patient. Nevertheless, the less complete study of a series of unselected cases gives other information that can only be obtained in this way and the two methods are complimentary. The loss of my longer paper-camera records of many of these patients as a result of enemy action has limited the study to shorter plate records.

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THE REFERENCE OF CARDIAC PAIN TO A PHANTOM LEFT ARM

BY

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Two cases in which anginal pain was referred in part to a " phantom " left arm are here recorded as a contribution to the problem of the mechanism of referred pain. In both, (1) the left arm had been amputated more than 25 years before the onset of cardiac pain, (2) there was evidence, both clinical and cardiographic, of gross myocardial damage, and (3) the " phantom " component of the pain was abolished, or significantly modified, by anæsthetizing the left brachial plexus.

Case I. Cardiac infarction; left bundle branch block. Phantom left arm since 1916 *following amputation through upper arm; cardiac pain referred to phantom and chest* (*April*, 1942). *Left brachial plexus block eliminated " phantom " component.*

H. T. (admitted 26/5/42), male, aged 45 years, in charge of social department of Tramways Depôt for 16 years; married; childless; wife healthy. Smokes 10 to 15 cigarettes daily but life-long teetotaler. No history of illness before 1916, and except for occasional colds and winter cough excellent health since discharge from the army. No significant family history of cardiovascular sclerosis.

On October 8, 1916, in France, he was wounded above the left elbow; ten days later the arm was amputated because of gangrene. Progress was good though three months later, owing to a persistent slight discharge, he had another operation. The wound then healed rapidly and completely. From the time of the amputation he has had a phantom arm, at first equal in length to his right arm, though gradually it has shortened to about half its original length; it moves with the shoulder but the elbow, forearm and hand remain fixed—the elbow at about 90° flexion, the forearm in mid-pronation-supination, and hand and finger joints slightly flexed—" as if clutching a ball." The hand dominates the phantom and he can discern all fingers clearly. The awareness of the phantom is not due to pain but to a tingling which he is usually able to ignore; " you get quite used to its being there." Wet weather intensifies the tingling.

FIG. 1.—Case 1. Showing the amputation stump and scar.

On April 6, 1942, an hour after rising, he was seized suddenly with pain in the substernal and left submammary region which spread to the stump and radiated down the phantom to the fingers, though the worst pain was felt in the phantom biceps region. Waterbrash and one small vomit accompanied this attack, which passed off completely in less than an hour; he went to his work that day and experienced no further pain, breathlessness, or other chest symptoms. During the following six days he had occasional twinges of the pain, but on April 12, whilst in bed, he had an attack similar in type, intensity, and duration to that of April 6. Since then the pain has recurred on undue effort, though the effort needed to produce pain radiating to the phantom varies; rest for a minute or two invariably eases the pain, which is induced by less effort in the morning than in the afternoon.

Examination showed a stump, four inches long (Fig. 1), with free and full movement at the shoulder joint and slight hyperæsthesia of the scar.

The heart was slightly enlarged and Dr. Roberts reported: Slight enlargement of left ventricle;

no evidence of pathological calcification, or of pulmonary lesion. The sounds were normal, the rhythm regular, and there was no murmur. B.P. 110/60. Pulse rate 78. Early locomotor brachial artery and slight retinal arteriosclerosis. There was typical left bundle branch block (Fig. 4A).

There were no significant clinical changes in the lungs, nervous system, or abdomen; no evidence of sepsis in mouth (edentulous) or naso-pharynx, and no pyrexia during his stay in hospital; no thyroid change, no skin rash, nor palpable lymph nodes. The urine was normal except for a few squamous cells and leucocytes with large numbers of calcium oxalate crystals. A blood count was also normal. The Wassermann reaction was negative.

On June 5, 1942, Mr. Edwards blocked the left brachial plexus with 60 c.c. of 1 per cent solution of procaine and Fig. 2 shows the extent of the resulting anæsthesia. No ocular or vascular changes

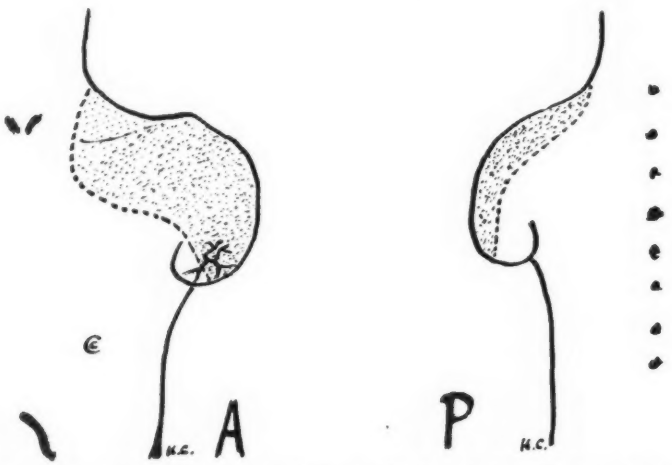

FIG. 2.—Case 1. The dotted area maps the anæsthesia resulting from the brachial plexus block. A. Anterior view. P. Posterior view.

were seen. The lower part of the scar remained sensitive though the patient felt that the whole phantom was numbed. Ten minutes later he walked 400 yards briskly; pain was felt in the chest only; the arm was quite free from pain though he had never previously experienced pain in the chest without radiation to the arm. When the anæsthesia passed off, exercise brought on pain in both chest and arm.

The variability in the intensity of effort required to produce the pain prevented quantitive observations on this patient. It is, however, of interest to note that since the brachial plexus block the phantom has shortened; he is no longer aware of arm or forearm, the hand appearing to be attached directly to the stump, and exertion now causes pain to appear in the chest and hand and/or stump simultaneously.

Case II. Angina of effort; coronary arteriosclerosis. Phantom left forelimb since 1916 *following disarticulation through shoulder joint; cardiac pain present and gradually intensifying for* 5 *weeks; referred to phantom, neck, jaws, and chest. Left brachial plexus block practically eliminated phantom component, and modified sequence of appearance of pain in different sites.*

J. T. (admitted 26/5/42), male, aged 51 years, a credit draper with no strenuous work; single; smokes 25 to 30 cigarettes daily and drinks an occasional beer. Father died at 52 from angina pectoris, mother at 74 from cerebral hæmorrhage, 5 sibs alive and well, a sister died aged 9 of spinal caries.

On August 9, 1916, his left humerus was shattered by machine-gun fire. He was treated at a field dressing station, but two days later, because of gangrene, the arm was disarticulated through the shoulder joint. A painful phantom appeared immediately, confined to the left hand, which was somewhat nearer to the shoulder than the right hand, and hanging at his side with fist clenched and nails digging into the palm, though the individual fingers were not distinguishable. The hand felt constantly swollen and burning, worse by night, and there were sharp stabbing pains on excitement. No voluntary movement of the hand or fingers was possible, but during the first two months he noticed that when he gripped with his right hand the phantom hand seemed to clench more tightly.

In 1917, an attack of acute appendicitis with operation caused an exacerbation of pain which subsided in a month. During the next 10 years, there was no change in the shape, site, or posture of the phantom, but the pain in it increased. In 1927, neuromata were excised from the scar; this operation improved the pain, caused the phantom to rotate inwards, and increased the appreciation of its site; but its shape and length relative to the shoulder remained unchanged at first, though very gradually during the next 15 years the limb shortened till now the phantom hand corresponds in site to the normal elbow. During the day the phantom was practically unobtrusive, though he could recall it by "thinking about it"; when he was tired, e.g. at the end of a day's work, the hot, swollen phantom reappeared. Thundery and wet weather always intensified the pain.

Five weeks before admission, after walking 300 yards up a steep incline, he noticed pain in his left shoulder and in the phantom hand "as though it had been battered to pulp"; this was followed when effort was continued by suffocation, constriction of the chest, pains in neck and jaws, and he felt "as though he would have died had he kept on walking." He rested and the pain eased. Since then, however, pain has recurred with gradually lessening exertion, until now walking 150 yards on the flat will bring on in unvarying sequence pain in the phantom, then in the neck, then a sense of constriction in the chest and choking. In the past fortnight there has been increasing breathlessness; now the act of undressing at bedtime leaves him breathless and exhausted and brings on the pain. He has had no cough, sputum, or other chest symptoms; no indigestion; no bladder disturbance; and no loss of weight.

Examination showed the scars of the disarticulation extending from the left acromio-clavicular

A B

FIG. 3.—Case 2. (A) Showing site of the amputation through the shoulder joint. (B) The scar is inked in and a pin-head neuroma indicated at X.

joint to the fifth rib in the mid-axillary line (Fig. 3); it was tender at X (Fig. 3B); pressure on this spot gave rise to a bursting sensation in the phantom similar to that experienced on exertion.

The heart was slightly enlarged and the X-ray report was: Slight enlargement of the left ventricle; bilateral simple fibrosis of the lungs. The sounds were normal, the rhythm regular and there was no murmur. B.P. 120/70. Pulse rate 84. Early locomotor brachial artery with slight silver wire thickening of retinal arteries. A cardiogram (Fig. 4B) showed low voltage and negative T_2 and T_3 waves.

He had slight emphysema, and an early arcus senilis. There was no organic lesion in the nervous system; no evidence of sepsis in mouth (edentulous), or naso-pharynx; no abdominal abnormality except the appendix scar which was well healed; no thyroid change; no rash; no palpable lymph nodes.

The urine was normal. The blood showed no anæmia. The Wassermann reaction was negative.

On June 5, 1942, Mr. Edwards blocked the left brachial plexus with 60 c.c. of 1 per cent solution of procaine. The diagram of the resulting anæsthesia (Fig. 5) shows that the lower part of the scar escaped, due to its dorsal nerve supply. On anæsthetization, the phantom lengthened and felt "like the gum when the dentist injects a local anæsthetic." No ocular or vascular changes were seen. About 20 minutes later he walked briskly on the flat (at a rate of 96 paces of two feet a minute): after 200 yards the suffocation and pain in the neck appeared but there was no pain in the hand; as he continued to walk he became conscious of the presence of the phantom and could discern the middle finger as a separate structure; and finally, when pain in the chest was so severe that he had to stop (after 600 yards), he was beginning to feel a mild bursting sensation in the phantom hand.

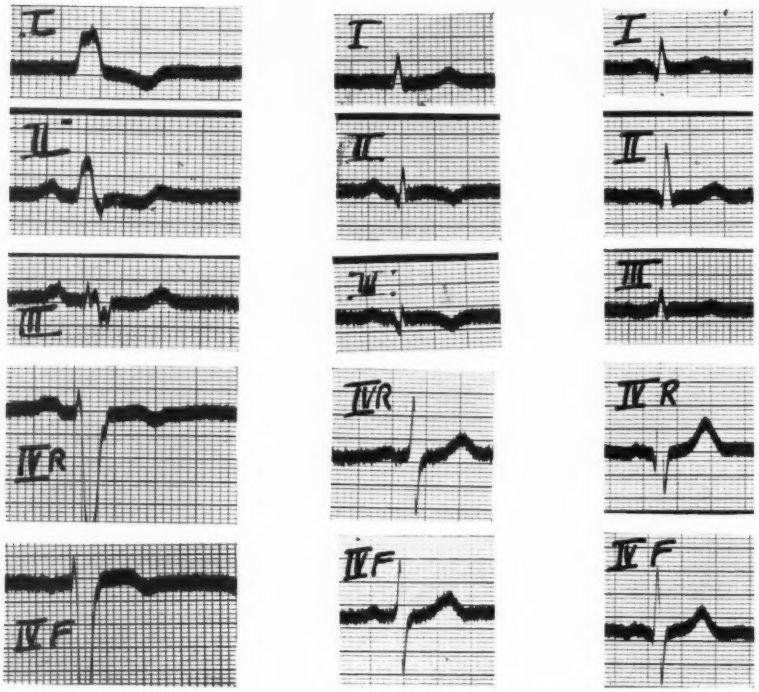

FIG. 4.—(A). Case I. Cardiogram showing left bundle branch block.
(B) Case 2. Cardiogram showing low voltage and negative T in leads II and III.
(C) Cardiogram from control patient with left upper phantom but no cardiac pain.

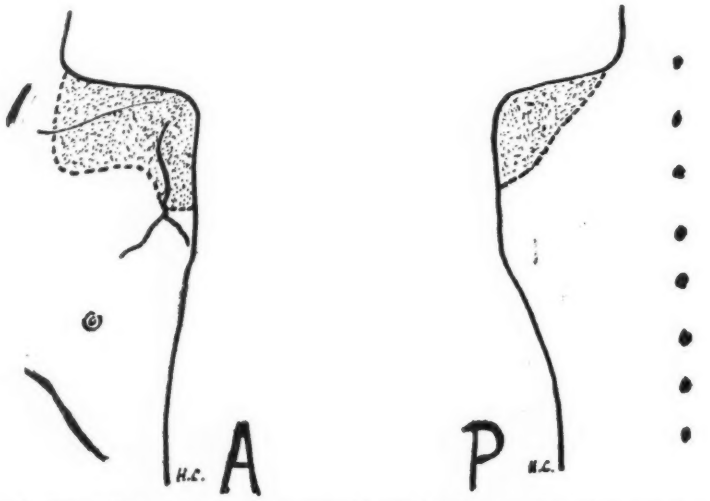

FIG. 5.—Case 2. The dotted area maps the anæsthesia resulting from brachial plexus block. A. Anterior view. P. Posterior view.

When the effects of the anæsthetic passed, the sequence of the angina reverted to phantom first (which appeared after about 150 yards walking on the level at a rate of 96 paces of 2 feet a minute), followed by suffocation, chest constriction, and neck pain (after 200–250 yards). A week later normal saline was injected into the plexus; this did not modify in any way the distribution of the pain, the order of appearance of its components, or the intensity of effort needed to induce it.

On July 20, 4 c.c. of 2 per cent novocaine was injected into the region of the neuroma at X (Fig. 3B). The effect on the cardiac pain was similar in type to that following the plexus anæsthesia. After walking 220 yards, constriction of the chest and choking appeared; as he continued this became very severe and then he felt the bursting pain in the phantom hand.

Comments

Fig. 4 C was taken from a patient with a phantom left arm who was otherwise quite well. It shows that fixing the left arm electrode to the amputation stump in no way modifies the cardiogram.

Great care was taken to avoid infiltrating the stellate ganglion when injecting the brachial plexus, as it is known that angina can be relieved by blocking the afferent impulses arising from the heart and passing through this ganglion. Apart from the visible evidence of the extent of the plexus infiltration two facts showed that the stellate ganglion had not been anæsthetized: first, the absence of any ocular or vascular signs of sympathetic paralysis; and secondly, the persistence of anginal pain in the areas not rendered anæsthetic by the brachial plexus block; had the stellate ganglion been blocked *all* afferent impulses from the heart would have been prevented from reaching the sensorium.

A careful search of the available journals has failed to reveal any comparable record of a patient who referred anginal pain to a "phantom." It is proposed in a later paper to discuss the bearing of our cases and the results of brachial plexus and neuroma block on current theories of referred visceral pain. It will be patent, however, that no such theory is tenable which fails to account for (i) reference of the pain to a phantom, and (ii) the effects of brachial plexus and neuroma block.

Summary

Two cases are recorded of cardiac pain referred to a phantom left arm.

Anæsthetization of the brachial plexus of the phantom caused, in one case, abolition of the phantom component of the cardiac pain, and in the other significant delay in the appearance of the phantom component which led to a reversal of the site of onset and spread of the cardiac pain.

EDITOR'S NOTE

It has been necessary to change the form of production in the interests of paper economy. The smaller margins will remain, but it may be possible to use a slightly larger style of printing in some or all subsequent numbers. If subscribers feel that this number is not so easy to read, they will be recompensed by knowing that this number in the fourth year of the war is the longest that has been published, even including the first introductory number in January, 1939.